GRANTA CES 2014 SELECTOR

User Manual & Getting Started Guide

GRANTA
MATERIAL INTELLIGENCE

Copyright © 2013 Granta Design Limited
CES Selector is a trademark of Granta Design Limited
www.grantadesign.com

Contents

Legal Matters 2

Chapter 1 Introduction 3
1.1 Read This First 3
1.2 About This Manual 4
1.3 Tutorials and Reference Information 5

Chaper 2 Installation 6
2.1 Introduction 6
2.2 Running the Setup Program 7

Chaper 3 Databases 8
3.1 Databases for Rational Materials Selection 8

Chaper 4 Getting Started with CES Selector. 10
4.1 Brief Description of CES Selector 10
4.2 Browsing and Searching 11
4.3 Comparing Records 17
4.4 Filtering and Screening 21
4.5 Tree Selection 24
4.6 Find Similar 25
4.7 Putting it All Together 26
4.8 Process Selection 31
4.9 Saving, Copying, and Report Writing 32

Chaper 5 Getting the Most Out of CES Selector. 34
5.1 Custom Selection 34
5.2 Performance Indices 42
5.3 Functional Data 44
5.4 Find Similar with Additional Criteria 46
5.5 Eco Audit 49
5.6 Hybrid Synthesizer 55

Toolbars and General Information. 58

Legal Matters

License Agreement

The software described in this document is furnished under a License Agreement and may be used or copied only in accordance with the terms of the License.

Copyright

This documentation for CES Selector and the software described in it are copyrighted ©1999-2013 Granta Design Limited, with all rights reserved. Under the copyright laws, neither the documentation nor the software may be copied, photocopied, reproduced, translated, or reduced to any electronic medium or machine readable form, in whole or in part, without the prior written consent of Granta Design Limited, except as described in the installation instructions.

Trademarks

Cambridge Engineering Selector, CES EduPack™, CES Selector™, CES Constructor™, and other CES related product names are Trademarks of Granta Design Limited.

Permission to Reprint, Acknowledgments, References

Reprinting

Selection charts, record data and extracts from hardcopy or online documentation copyrighted by Granta Design Limited may be reprinted in published works provided:

(i) prior written permission is obtained for every instance from Granta Design Limited by mail, fax, or electronic mail (contact details on back cover of this manual);

(ii) each such chart, datasheet, document, etc, is accompanied by an acknowledgment of the form:

Chart/data/etc. from CES Selector 2014, Granta Design Limited, Cambridge, UK, 2013 (www.grantadesign.com).

Bibliographic References

When referring to the CES Selector software in publications, the bibliographic reference is:

CES Selector software, Granta Design Limited, Cambridge, UK, 2013 (www.grantadesign.com).

When referring to this User's Manual in publications, the bibliographic reference is:

CES Selector User's Manual (6th Edition), Granta Design Limited, Cambridge, UK, 2013 (www.grantadesign.com).

Chapter 1 Introduction

1.1 Read This First

CES Selector is a powerful tool that aids critical design and business decisions for engineering enterprises and materials producers. Based on rational material selection methodologies, CES Selector enables rigorous and quantitative analysis of:

• Optimal material and process selection for component design - maximizing performance while minimizing factors such as volume, mass, cost, carbon footprint …

• Positioning of materials - how do your materials compare against your competitors?

• Material development - identify new property combinations that will give you a competitive advantage in the market.

The unique selection methodology, software tools, and databases of CES Selector enable candidate materials and processes to be rapidly identified using a systematic, auditable approach to product design.

The main aim of this manual is to give a brief insight into the capabilities of the selection tools as well as practical experience through the exercises. However, in order to benefit from the full power of CES Selector, you should also refer to the book '*Material Selection in Mechanical Design*', by Prof. Mike Ashby, which provides an in-depth review of the rational selection methodology.

CES Selector consists of the following components:

• Selector software, including Browse, Search, Selection, and Comparison tools.

• Optional add-on tools: Eco Audit Tool, Hybrid Synthesizer, and CES Constructor.

• MaterialUniverse and ProcessUniverse data modules, containing complete and comparable data covering all standard material grades and manufacturing processes. Includes links to external data sources and '*Design Notes*' that enable users to drill down to the origins of properties.

• A range of specialist databases that provide information on a wide range of individual grades and material conditions (e.g. temper, form, statistical basis, filler levels).

• '*Material Selection in Mechanical Design*' textbook that provides and in-depth explanation of the rational material selection methodology used within CES Selector.

For the latest information, please see www.grantadesign.com/ces.

1.2 About This Manual

This manual contains 5 chapters:

Chapter 1 Introduction
provides information about this manual and where to find help.

Chapter 2 Installation
describes the system requirements and the installation options.

Chapter 3 Databases
describes databases for rational material selection.

Chapter 4 Getting Started with CES Selector
provides a brief overview of the main features and capabilities of CES Selector in tutorial format.

Chapter 5 Getting the Most out of CES Selector
provides and introduction to some additional tools and features of CES Selector.

1.3 Tutorials and Reference Information

Information on getting started with the CES Selector software can be found in Chapter 4 and Chapter 5 of this manual.

A comprehensive set of tutorials covering use of the software as well as reference information about all aspects of the software can be found in the in-software Help system.

The CES Help contains a wealth of information about the system, including details of the selection methodology, tables of material indices, solutions to standard engineering problems, and material and process selection case studies with loadable project files.

Chaper 2 Installation

2.1 Introduction

This part of the User Manual provides instructions for registering and installing your copy of the CES Selector system.

System Requirements

To run the CES Selector software you will need:

• A compatible Microsoft® Windows® operating system;
Windows XP 32-bit SP3,
Windows Vista 32-bit or 64-bit SP2,
Windows 7 32-bit or 64-bit,
Windows 8 32-bit or 64-bit.

• 1 GB of RAM.

• 2 GB of available hard disk space.

• Internet connection (for the Web Search functionality).

• Microsoft .NET Framework Client version 4.0 and Visual Studio Runtime; if these are not already installed on your PC, you will be given the option to add them automatically to the CES Selector installation process.

• Administrator rights.

License Options

CES Selector is licensed per user. The number of users specified on the license agreement represents the number of different employees who can use the software.

For each user, the software can be installed on more than one machine, for example on both work and home computers. However, it should not be installed on a machine that provides access to users not covered by the license agreement.

Note: The license is not a floating or concurrent license. As a result, it can only be used by the number of people specified on the license agreement.

Configuration

The CES Selector software needs to be installed on individual PCs.

All of the databases supplied with CES Selector are installed by the installation procedure described in Chapter 2.2. Additional CES Selector databases can be purchased and installed in the same way.

If you would like further assistance, please contact Granta (support@grantadesign.com).

2.2 Running the Setup Program

If you have installed a previous version or evaluation copy of CES Selector, we recommend that you uninstall it before installing this version. To do so, use Add or Remove Programs in Windows Control Panel.

To install the software, run *setup.exe* and follow the instructions in the installation wizard. You can use **Cancel** or **Exit Setup** to quit the installation when they are displayed.

You will require your license key to install the software.

Note that the CES Constructor software is not automatically distributed with every CES Selector system. It will only be available if you have purchased an appropriate license.

Chaper 3 Databases

3.1 Databases for Rational Materials Selection

The MaterialUniverse and ProcessUniverse data modules are used with CES Selector to create high quality databases that you won't find elsewhere. They are designed for like-to-like comparisons across the whole spectrum of material and processing possibilities. Typical material databases do not allow this - the most common reasons being: 'holes in the data'; and different properties reported for different materials. This makes it difficult to compare different classes of materials.

Universe data modules solve the problem by conforming to strict database design principles. These principles are reviewed below, with reference to the MaterialUniverse data module.

Complete spectrum represented

The MaterialUniverse data module contains a representation of virtually every commercial engineering material in every class. This means that you can be sure that you have considered all material possibilities for any particular application.

Each material represented only once

Multiple instances of the same material from different producers are consolidated into one representative record. This reduces the complexity of the engineer's search for the best material.

Property ranges

Properties of real materials are seldom exact - there are inevitable variations from batch to batch and manufacturer to manufacturer. These variations are captured in a Universe data module by a range - the range may be small for a property such as density, but relatively large for price or toughness.

Complete property set

In a Universe data module, there is a value for every property on the datasheet. If the value is not known experimentally, it has been estimated by using intelligent estimating techniques based on well-established correlations between material properties, using their fundamental physics.

Quality checks

Granta has examined hundreds of material datasets over the years from various sources and, without exception, they contain errors - sometimes by as much as 1000%! To minimize errors in the Universe data modules, strict data checking procedures are used. These include checks that properties for specific material classes fall within acceptable ranges, and powerful science-based checks on the correlations between properties.

Normalization

All properties are presented in the same unit system, which can be chosen by the user. Properties that are reported in different ways for different materials classes are equivalenced to enable comparison.

Hierarchy

The carefully-constructed record hierarchy allows simple and rapid navigation to all records in the data module.

The Result

Applying these principles required a great amount of work in data collection and processing. The MaterialUniverse data module represents over 50 man-years of effort spread over a 15-year period. The rewards of this effort are immediate and numerous with the MaterialUniverse and ProcessUniverse databases used in combination with the CES Selector software.

Chaper 4 Getting Started with CES Selector

The following exercises give an overview of CES Selector and will teach you how to use the core functionality. The exercises in Chapter 5 go into further detail and explore some of the software's more specialized features. There is also comprehensive help file within the software that gives more detailed guidance, as well as case studies with loadable project files.

4.1 Brief Description of CES Selector

There are three main tools in CES Selector:

- BROWSE Explore the database and retrieve records via a hierarchical index or tree.
- SEARCH Find information via a full-text search of records.
- SELECT The central hub of CES Selector, used to apply the Rational Material Selection methodology. A powerful selection engine that identifies records that meet an array of design criteria and enables trade-offs between competing objectives.

The following exercises cover the use and functionality of these tools.

4.2 Browsing and Searching

Exercise 1 Opening the Database

If you have more than one database installed, CES will show the Databases dialog. The following exercises use the **MaterialUniverse** and **ProcessUniverse** tables, which are part of every Granta database.

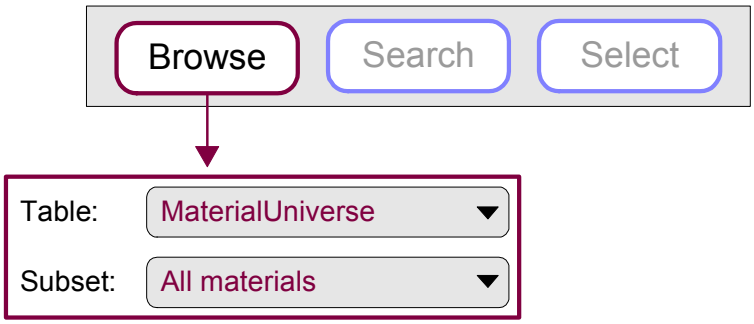
CES Selector then opens the Edition Homepage. There is a graphic for each data module (a collection of tables). Hover over a data module to see the tables it contains. Click on a table name to show a description below. Use the **More information** link below the modules to show detailed descriptions of all of the tables in a data module.

• Swap between the available tables and see how the different tables have different applications and data
Click on a table in the Edition Homepage to select it. The information below the table graphic displays information on the currently-selected table. You can also change the selected table from the graphic in the More information page.

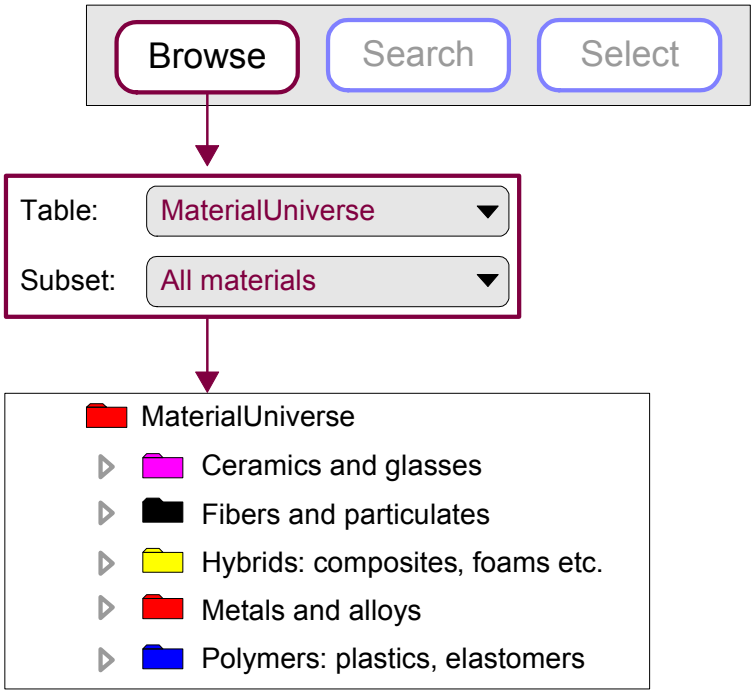
• Change to the PROCESSUNIVERSE table
*Click on MaterialUniverse and notice that the **Browse** tree in the left pane updates.*

• CLOSE the HOMEPAGE
*Click on the cross at the top of the Homepage tab. This page can be reopened at any time from **View** menu - **Home**.*

• Change to the MATERIALUNIVERSE table
*With the Homepage closed, navigate to different tables using the **Table** drop-down in the **Browse** pane.*



Exercise 2 Browse Materials



Select the **Table** MaterialUniverse and the **Subset** All materials.

• Find a record for STAINLESS STEEL

• Find a record for CONCRETE

• Open the GENERIC record for POLYPROPYLENE
Generic records are records at the folder level and give general information on the material, rather than data on a specific variant. Generic records have their own icon . Double-click to open.

• Open a POLYPROPYLENE record
Double-click on the record name in the tree

Click on hyperlinked attribute names for design notes, which provide background information on properties, test notes, and selection guidelines. Right-click on the datasheet to see a context menu with further actions e.g., locate in Browse tree, copy the datasheet, print the datasheet, export the data to an FE package format.

The design note for Young's modulus:

Young's modulus

Stiffness in tension (also called Tensile Modulus, Elastic Modulus, Modulus of Elasticity).

Test notes

Young's modulus (E) is the slope of the initial linear-elastic part of the stress-strain curve in tension.

Material selection notes

Use to select materials with sufficient stiffness (high value) or sufficient compliance (low value).

Modulus in tension, flexure, and compression are similar for most materials so can be interchanged for approximate work.

Typical values:

Flexible plastics and elastomers	< 1 GPa
Unfilled plastics	1–4 GPa
Reinforced plastics	5–25 GPa
Ferrous metals	70–250 GPa
Non-ferrous metals	10–310 GPa
Technical ceramics	20–700 GPa
Ceramics and glasses	1–120 GPa

Click to see science note.

For more information on the property and to drill down to the underlying science, follow the hyperlink to the science note.

Part of a datasheet for the material Polypropylene:

PP (Copolymer, UV stabilized)

General properties

Designation

Polypropylene (Copolymer, UV stabilized)

Composition overview

Composition (summary)

copolymer of propylene (CH2-CH(CH3))n and up to 7% ethylene (CH2CH2)m or other comonomer + UV stabiliser additives

Price

Price	*	1.59	-	1.88	USD/kg

Physical Properties

Density		899	-	909	lb/in^3

Mechanical properties

Young's modulus		1.23	-	1.26	GPa
Yield strength (elastic limit)		23.6	-	26.9	MPa
Tensile strength		23.4	-	24.6	MPa
Elongation		139	-	865	% strain
Compressive strength	*	29.5	-	31	MPa
Flexural strength (modulus of rupture)	*	31.3	-	35.9	MPa
Shear modulus	*	0.438	-	0.449	GPa
Bulk modulus	*	2.26	-	2.32	GPa
Poisson's ratio	*	0.405	-	0.413	
Hardness - Vickers	*	7.37	-	7.74	HV
Fatigue strength at 10^7 cycles	*	9.36	-	9.83	MPa
Fracture toughness	*	1.36	-	1.43	ksi
Mechanical loss coefficient (tan delta)	*	0.0312	-	0.0328	

Thermal properties

Melting point	*	145	-	153	°C
Glass temperature		-24	-	-16	°C
Maximum service temperature	*	64.6	-	81.7	°C
Minimum service temperature	*	-25	-	-10	°C
Thermal conductivity	*	0.197	-	0.205	W/m.°C
Specific heat capacity	*	0.448	-	0.457	J/kg.°C
Thermal expansion coefficient		65.8	-	67.4	µstrain/°C

• Find PROCESSES that can shape POLYPROPYLENE using the ProcessUniverse LINK at the bottom of the datasheet.

Exercise 3 Browse Processes

Browse ProcessUniverse: All processes

• Find a record for INJECTION MOLDING

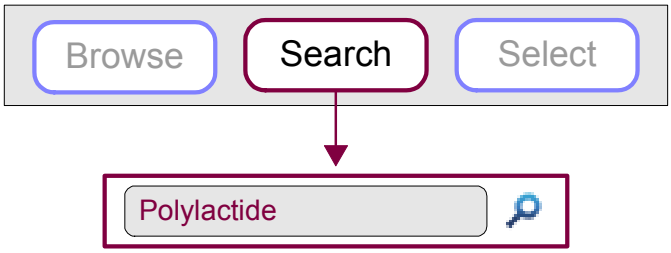
• Find record for LASER SURFACE HARDENING AND MELTING

• Find record for FRICTION WELDING (METALS)

• Find materials that can be DIE CAST, using the LINK at the bottom of a record for DIE CASTING

Exercise 4 The Search Facility

• Find the material POLYLACTIDE



The search term is highlighted in records opened from the search results.

• Find the materials for CUTTING TOOLS

• Find the process RTM

Note: The folder name is also included in the search. If the term appears in a folder name, all records under that folder will be returned; for example, a search for **ceramic** would return all records in the folder named **Ceramic**.

Wildcards are automatically added to the end of each search term.

• Enter the search term ALUM
*Records for or containing **Alumina** and **Aluminum** are returned.*

• The following search operators are available:

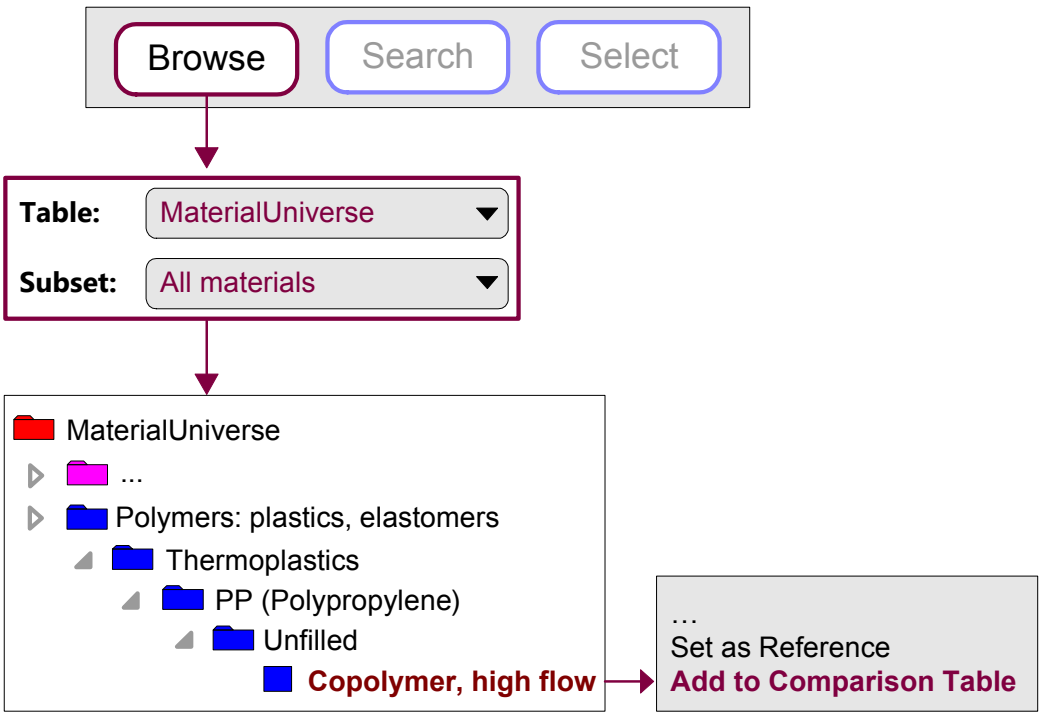
AND	Finds records containing both the search terms, so **steel AND alloy** returns only records containing both the words **steel** and **alloy**
OR	Finds records containing either search term, so **steel OR alloy** returns all records that contain **steel**, **alloy**, or **both**
NOT	Finds records containing the first search term, but not the second, so **steel NOT alloy** returns only records with the word **steel** but without the word **alloy**
Phrase Search	Finds the exact search term, so **“steel alloy”** will return only records containing the exact phrase **steel alloy**
Parentheses	Used to group search terms, so **iron AND (ore OR cast)** will return the records containing **iron** and containing either **ore**, **cast**, or **both**

Note: AND operators are automatically added when a search has two or more terms and no other operators have been entered.

4.3 Comparing Records

The performance of different materials can be compared by creating Comparison Tables or Property Charts.

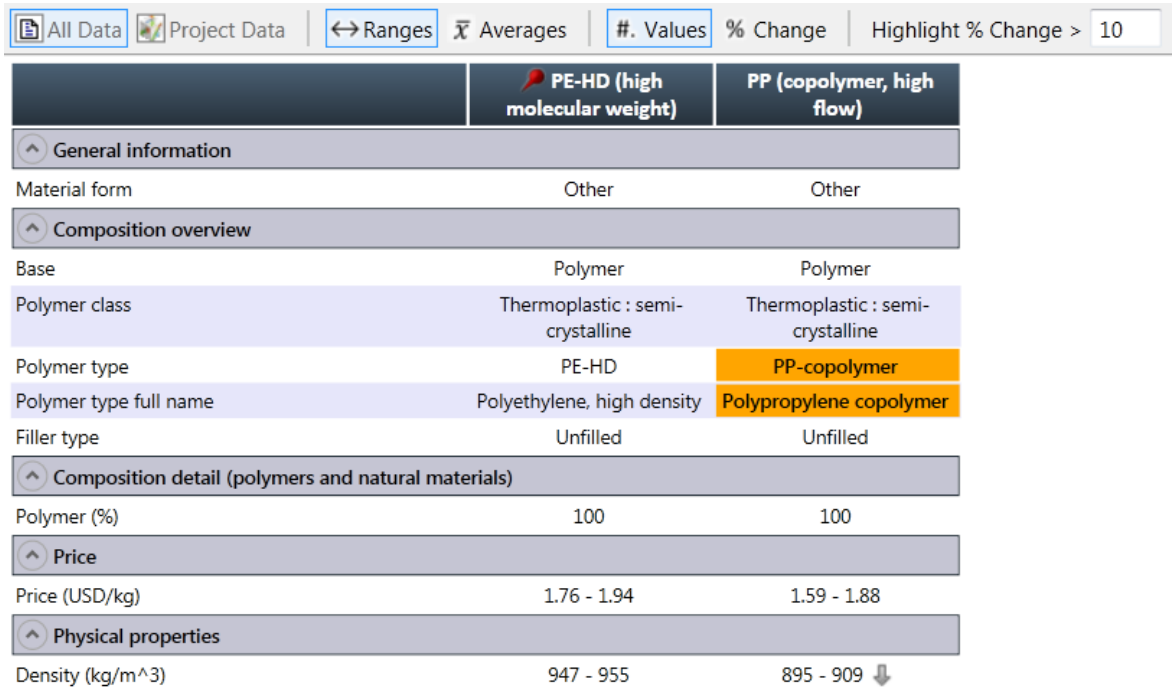
Exercise 5 Comparing Records



• Add an unfilled PP (Polypropylene) and an unfilled high-density PE (Polyethylene) record to a COMPARISON CHART
*Find an example of each in the **Browse** tree, then right-click and select **Add to Comparison Table**.*

• Set the PE-HD record as the reference record

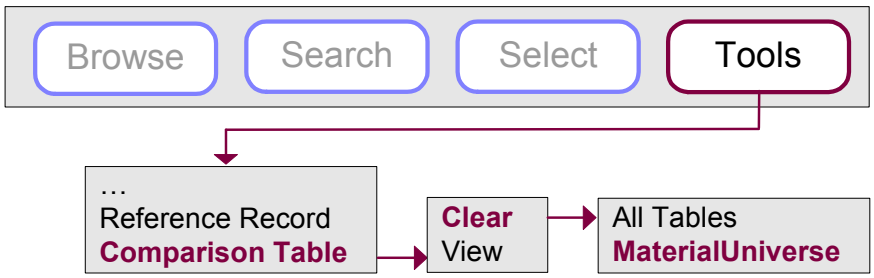
*Hover over the record name in the comparison table and click the **Set as Reference** icon* .



	PE-HD (high molecular weight)	PP (copolymer, high flow)
General information		
Material form	Other	Other
Composition overview		
Base	Polymer	Polymer
Polymer class	Thermoplastic : semi-crystalline	Thermoplastic : semi-crystalline
Polymer type	PE-HD	PP-copolymer
Polymer type full name	Polyethylene, high density	Polypropylene copolymer
Filler type	Unfilled	Unfilled
Composition detail (polymers and natural materials)		
Polymer (%)	100	100
Price		
Price (USD/kg)	1.76 - 1.94	1.59 - 1.88
Physical properties		
Density (kg/m^3)	947 - 955	895 - 909

• Change the display to show the differences relative to the reference record as percentages
*Click **%Change** in the comparison table toolbar.*

• Clear the Comparison Table

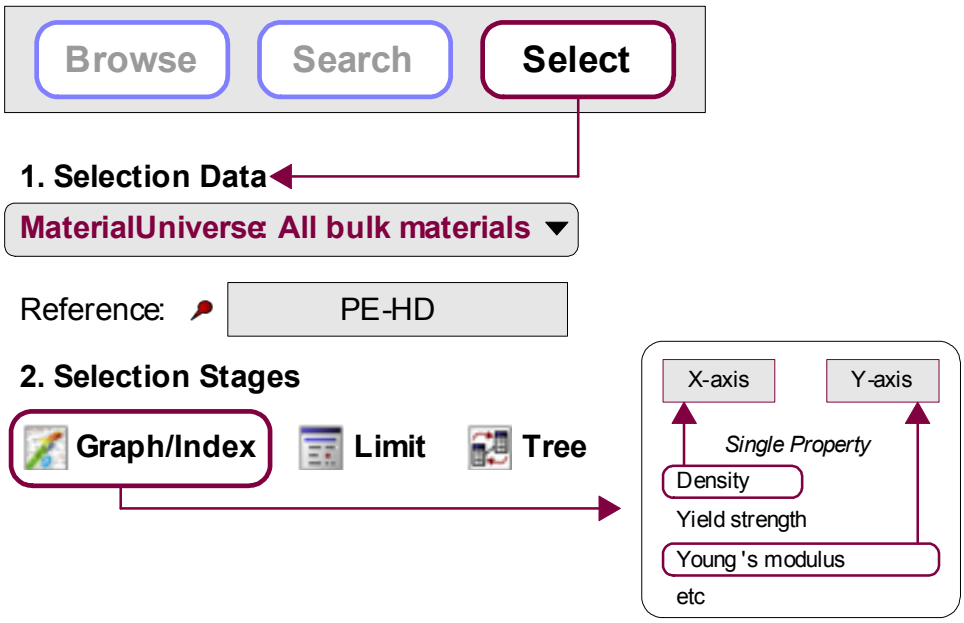


Exercise 6 Creating a Property Chart

Select MaterialUniverse: All bulk materials

• Make a BAR CHART of YOUNG'S MODULUS (E)
*Set the y-axis to **Young's modulus** and leave the x-axis at **<None>**.*

• Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ)
*Set the y-axis to **Young's modulus** and set the x-axis to **Density**. Leave the **Axis Settings** defaults to create a log-log plot.*

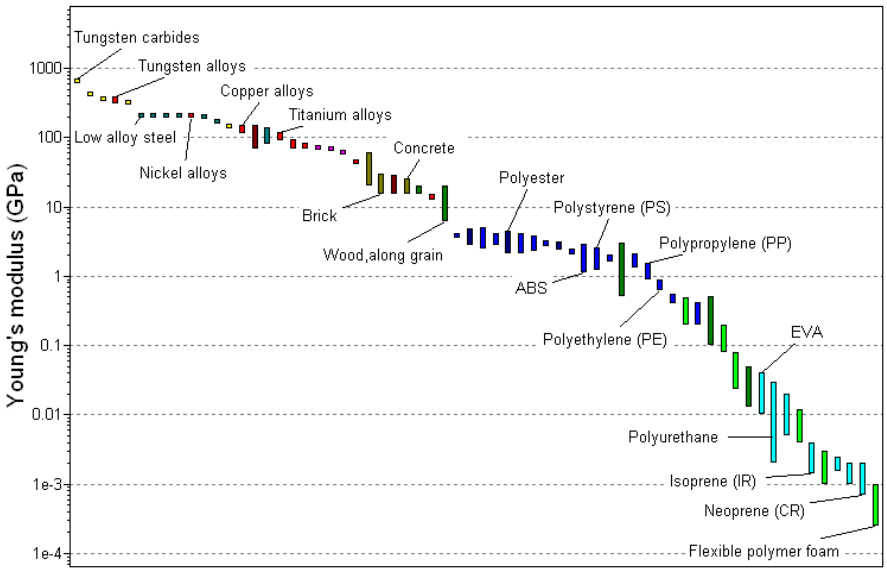


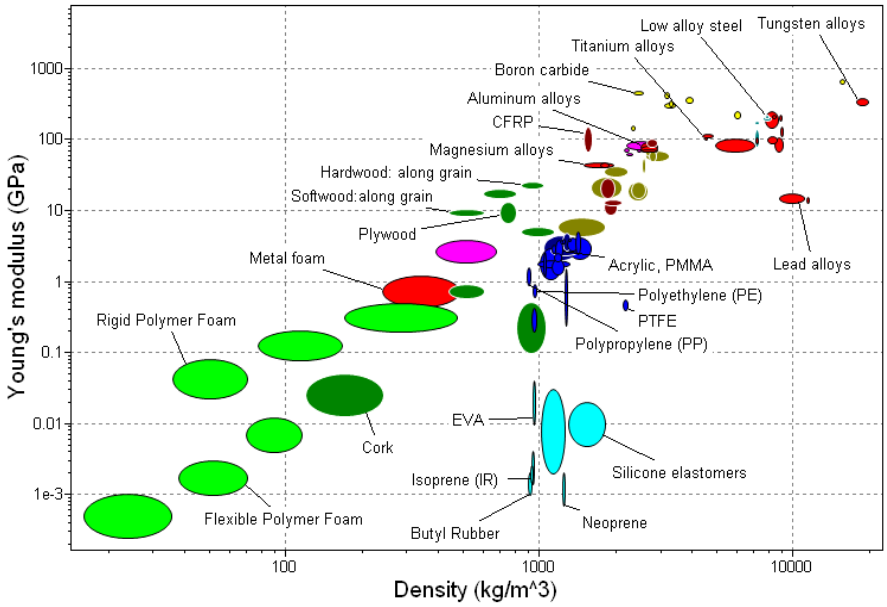
Records on a chart can be clicked to add labels, or double-clicked to open the corresponding datasheet. Labels can be dragged, or deleted using the DEL key.

• Show the Reference Record chart

*Click the **Show Reference Record** icon* *in the Graph Stage toolbar; in the chart, all records except the reference record are grayed out.*

• DELETE THIS STAGE
*Right-click on stage in **Selection Stages** and select **Delete**.*


Tungsten carbides
Tungsten alloys
Copper alloys
Titanium alloys
Low alloy steel
Nickel alloys
Concrete
Brick
Polyester
Polystyrene (PS)
Wood,along grain
Polypropylene (PP)
ABS
Polyethylene (PE)
EVA
Polyurethane
Isoprene (IR)
Neoprene (CR)
Flexible polymer foam
Young's modulus (GPa)
1000
100
10
1
0.1
0.01
1e-3
1e-4

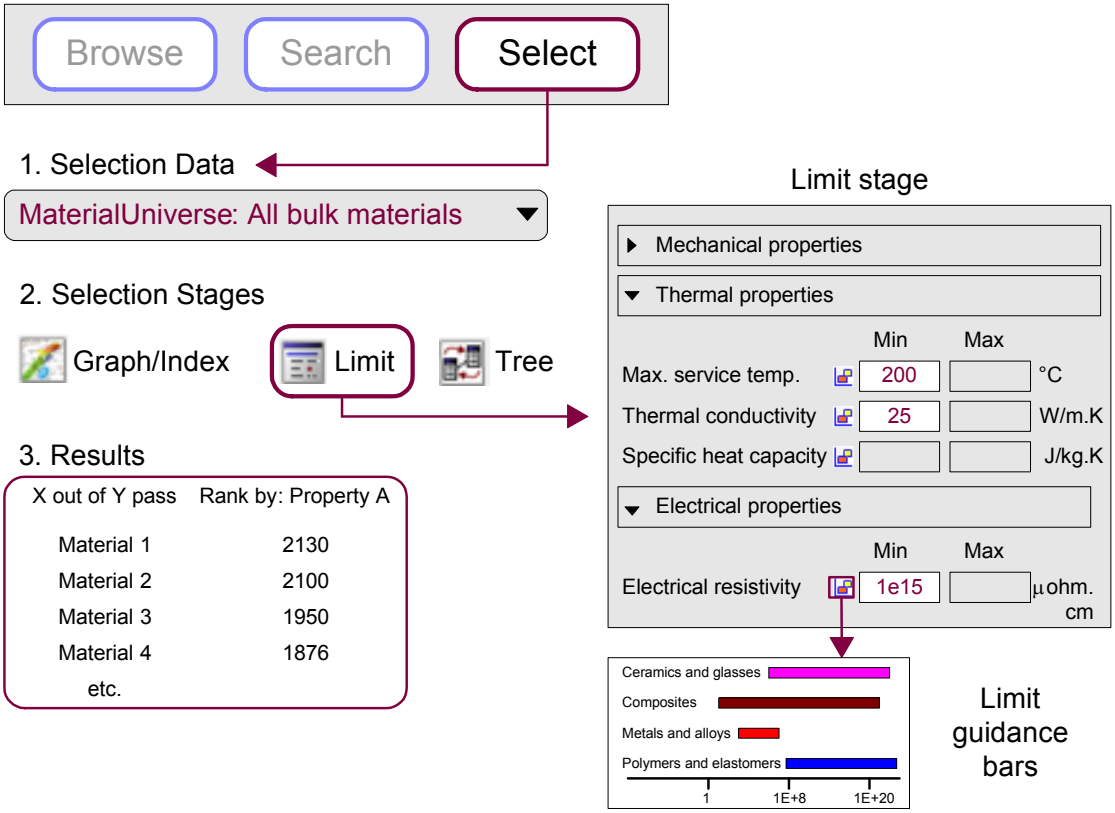

Low alloy steel
Tungsten alloys
Titanium alloys
Boron carbide
Aluminum alloys
CFRP
Magnesium alloys
Hardwood: along grain
Softwood:along grain
Plywood
Metal foam
Acrylic, PMMA
Lead alloys
Polyethylene (PE)
PTFE
Polypropylene (PP)
Rigid Polymer Foam
EVA
Cork
Silicone elastomers
Isoprene (IR)
Flexible Polymer Foam
Butyl Rubber
Neoprene
Young's modulus (GPa)
1000
100
10
1
0.1
0.01
1e-3
100
1000
10000
Density (kg/m^3)

4.4 Filtering and Screening

Exercise 7 Selection Using a Limit Stage

• Find materials with:

MAX. SERVICE TEMPERATURE	> 200 °C
THERMAL CONDUCTIVITY	> 25 W/m.°C
ELECTRICAL RESISTIVITY	> 1e15 µohm.cm



*Use the limit bars for guidance on suitable values. Enter the limits – minimum or maximum as appropriate – and click **Apply**. If a reference record is set, its values for each property will be shown to the right of the min/max entry boxes.*
Example results: Aluminum nitride, Alumina, Silicon nitride.

Some properties have discrete values, rather than numeric ranges.

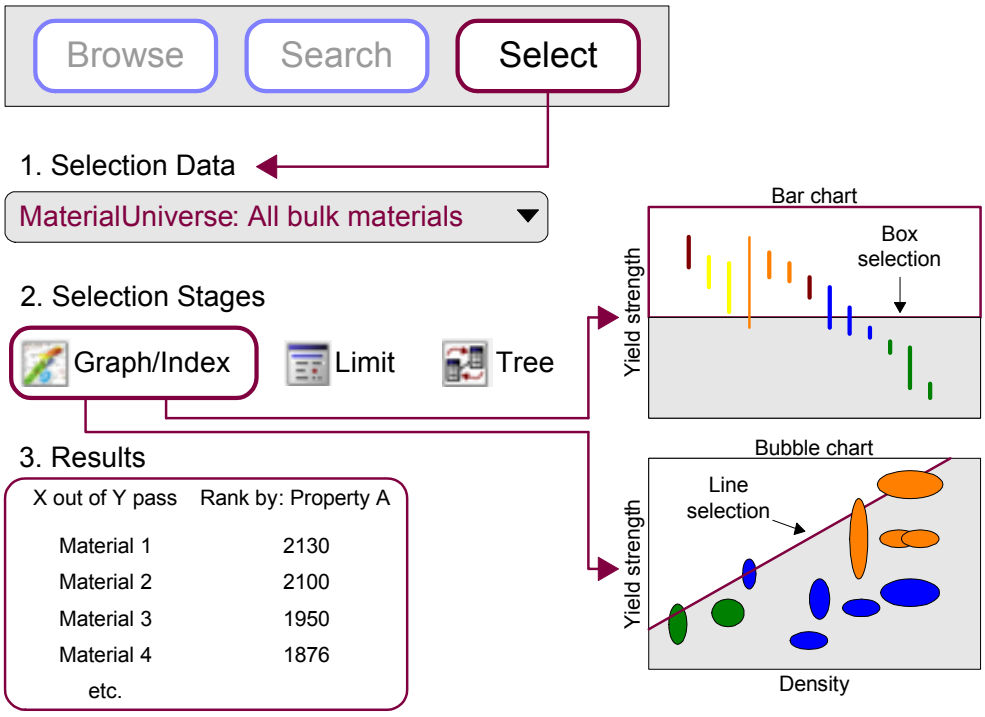
• Edit this limit stage and search for materials with non-opaque TRANSPARENCY.
*Under **Optical Properties**, refine by transparency using the drop-down and tick **Translucent**, **Transparent**, and **Optical quality**. Click **Apply**.*
Example results: Alumina (translucent) and Diamond.

• DELETE THIS STAGE

Exercise 8 Selection Using a Graph Stage

When plotted on a Graph Stage, records can also be filtered using the charting Box and Line Selection tools. This provides a more qualitative approach to filtering.

• Make a BAR CHART of YIELD STRENGTH (σ_y)
*Set the y-axis to **Yield strength (elastic limit)**.*



• Use a BOX SELECTION to find materials with high values of YIELD STRENGTH

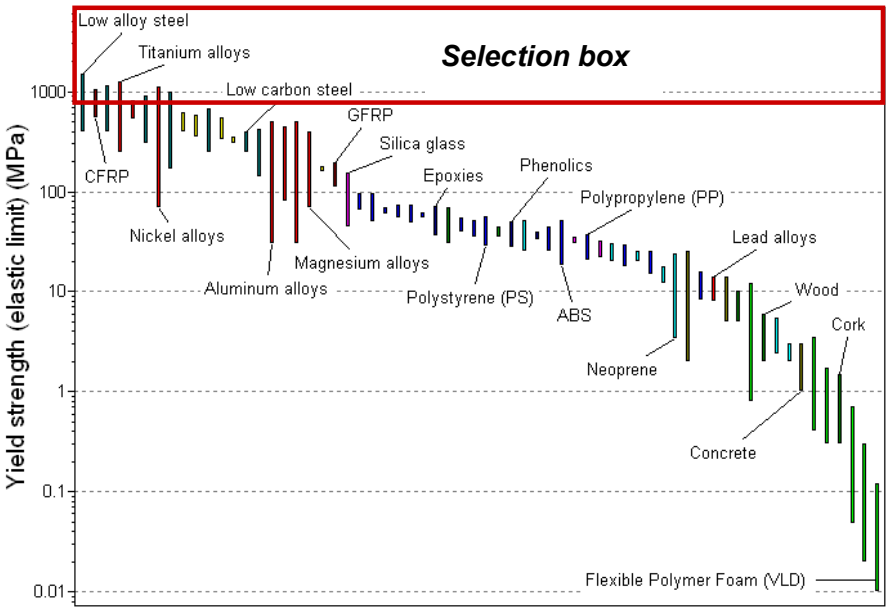
*Click **Box Selection** , then click-drag-release to define the box.*

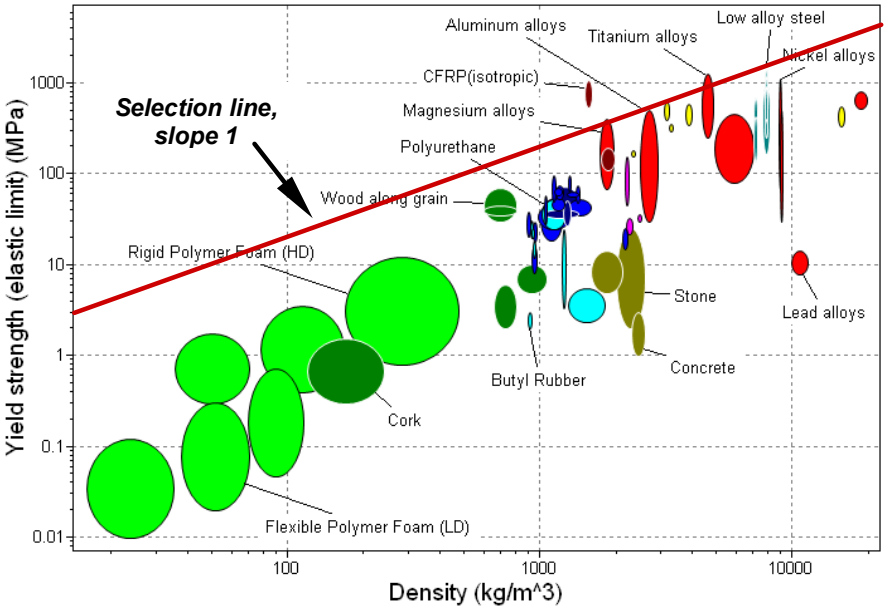
• Add DENSITY (ρ) to the other axis
*Either: highlight Stage 1 in Selection Stages, right-click and choose **Edit Stage** from the menu; or double-click the axis to edit.*

• Use a BOX SELECTION to find materials with high STRENGTH and low DENSITY

• Use a LINE SELECTION to find materials with high values of the specific strength σ_y / ρ

*Click **Gradient-Line Selection** , then enter slope in the dialog, in this case 1. Click on the graph to position the line through a particular point. Click above or below the line to select an area, in this case above the line for high values of σ_y / ρ. Drag the line upwards to refine the selection to fewer materials.*





• Rank the results by specific strength (YIELD STRENGTH / DENSITY)
Rank by Stage 1: Performance Index and click on results column to reverse the order.

Example results: CFRP, Titanium alloys, Magnesium alloys.

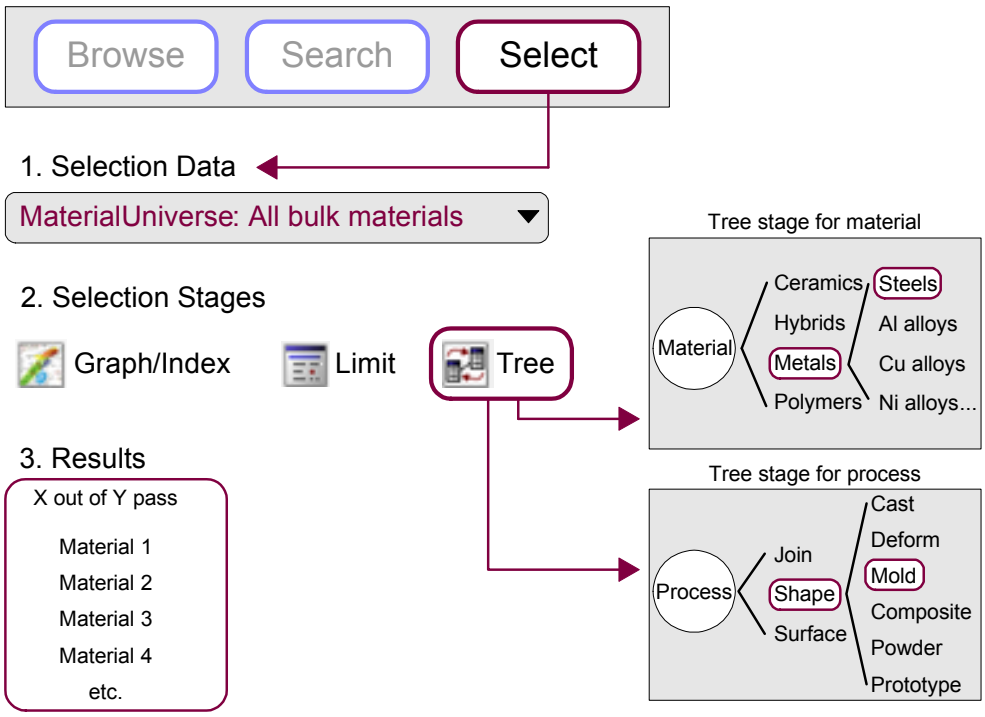
• DELETE ALL STAGES

4.5 Tree Selection

Using a Tree Stage, records can be filtered based on their links to records in other data tables, or based on the database hierarchy (tree).

Exercise 9 Selection Using a Tree Stage

• Find materials that can be MOLDED
*In the Tree Stage window, select ProcessUniverse, navigate to **Molding**, and click **Insert** followed by **OK**.*



• DELETE THIS STAGE

• Find processes to join STEELS
*Select Processes: Joining processes. In the Tree Stage window, select MaterialUniverse, expand **Metals and alloys** in the tree, select **Ferrous**, and click **Insert** followed by **OK**.*

• DELETE THIS STAGE

4.6 Find Similar

Materials in the database can be ranked based on their similarity, or nearness, to a specified material. This is useful for finding replacement or equivalent materials. The way in which nearness is calculated can be tailored to account for specific design requirements behind the initial material choice.

Exercise 10 Find Similar and Nearness Settings

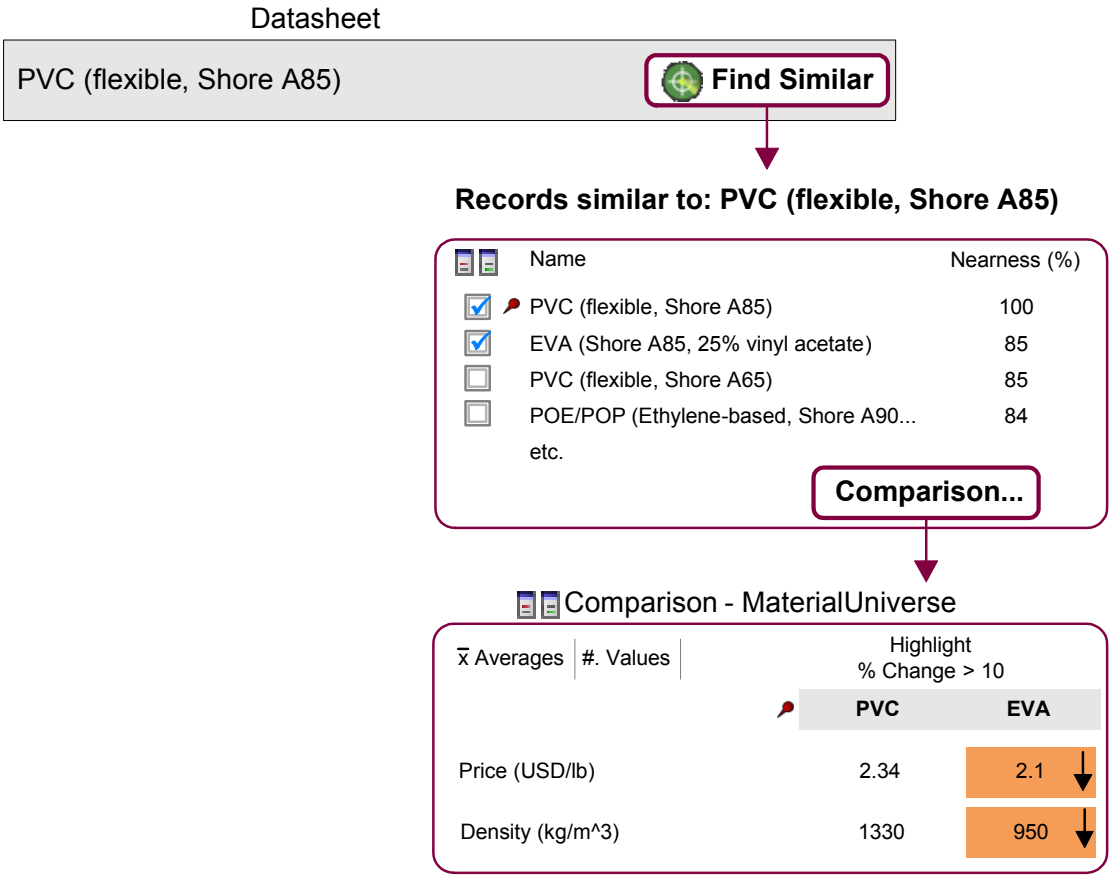
• Open the datasheet for PVC (flexible, Shore A85)

• Find similar materials
Click Find Similar and confirm changing the reference record if prompted.

Available materials are ranked by their similarity to the reference material. In this instance, calculations are based on the default nearness criteria for this table.

• Compare the nearest material
Select the first result - EVA (Shore A85, 25% vinyl acetate) - and click Comparison.

A comparison report is generated, showing the selected result and the reference record. Significant differences in the attribute values are highlighted.



4.7 Putting it All Together

Exercise 11 Combining Filtering and Charting Tools

Select MaterialUniverse: All bulk materials and set the Reference Record to **POM (thermoplastic)**.

• Find materials with:

DENSITY	< 2000 kg/m^3
STRENGTH (Elastic limit)	> 60 MPa
THERMAL CONDUCTIVITY	< 10 W/m.°C

Add a Limit Stage with three criteria.

• Filter the results to find those that can be THERMOFORMED
Add a Tree Stage and select ProcessUniverse - Shaping - Molding.

• Rank the results by PRICE
*Add a Graph Stage with a bar chart of **Price**. On the Graph Stage, all materials that fail one or more stages are grayed out. The **Results** pane shows the materials that pass all stages.*

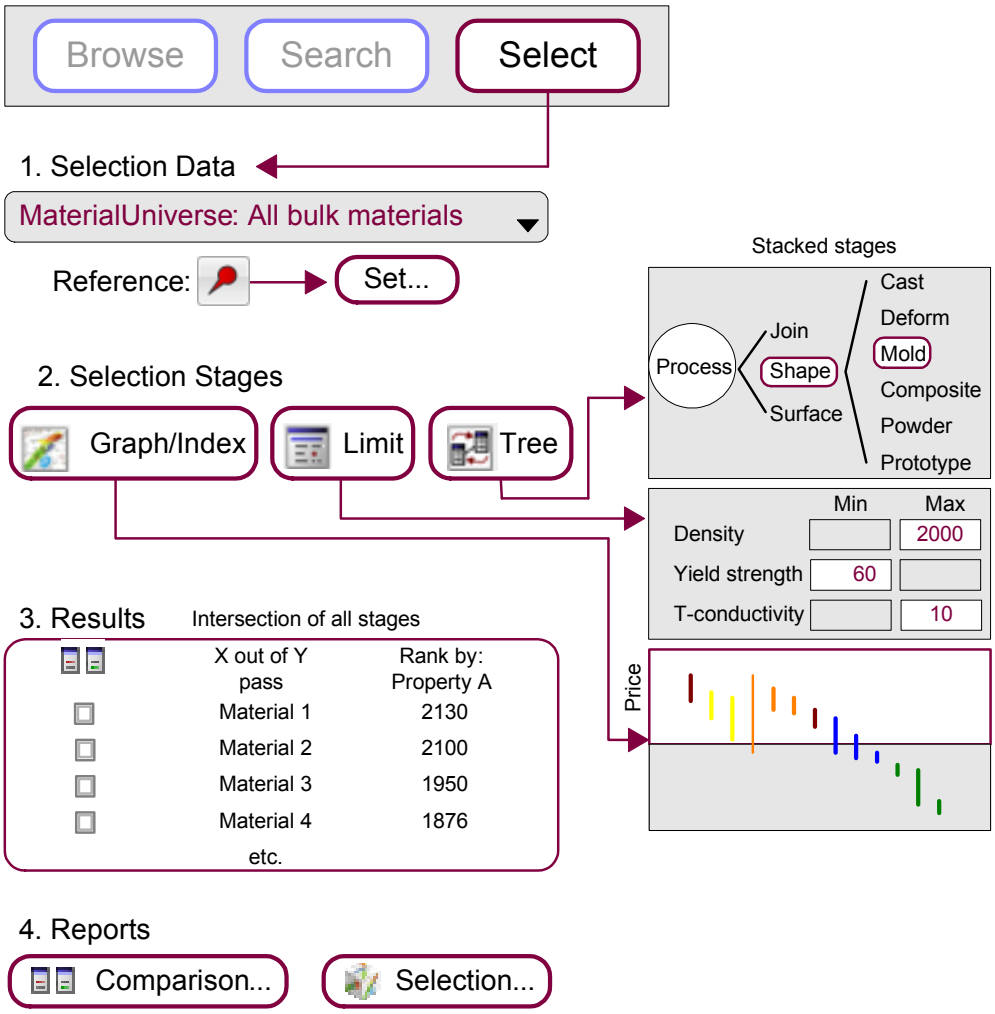
Example results, lowest PRICE first: PET-GF, PLA, PET ...

• Add the three materials with the lowest price to the Comparison Table
*Tick the checkboxes for the top three records in **Results**.*

• VIEW the Comparison Table
*Click **Comparison** below **Results**.*

• GENERATE the Selection Report
*Click **Selection** below **Results**.*

A selection report is created, containing a summary of the selection project on the first page, details of each selection stage on the following pages, and the comparison table on the final page.


Browse
Search
Select
1. Selection Data
MaterialUniverse: All bulk materials
Reference:
Set...
2. Selection Stages
Graph/Index
Limit
Tree
Stacked stages
Process
Join
Shape
Surface
Cast
Deform
Mold
Composite
Powder
Prototype
Min
Max
Density
2000
Yield strength
60
T-conductivity
10
Price
3. Results
Intersection of all stages
X out of Y pass
Rank by: Property A
Material 1
2130
Material 2
2100
Material 3
1950
Material 4
1876
etc.
4. Reports
Comparison...
Selection...

Exercise 12 Finding Supporting Information

The following exercise requires an Internet connection.

CES Selector translates the material ID to search strings compatible with a group of high-quality material and process information sources and delivers the hits. Many of the sources require a subscriber-based password. The ASM source is particularly recommended.

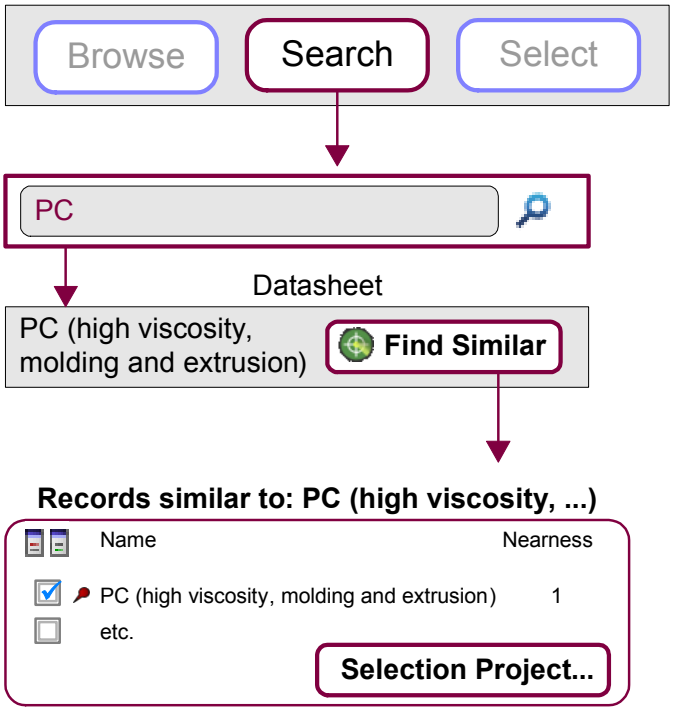
• Search the web to find more information on PET
*With the **PET** datasheet open, click on **Search Web**.*

Exercise 13 Search and Find Similar

• Search for the material PC and open the datasheet
*Use Search to find and display **PC (high viscosity, molding and extrusion)**.*

• Find records similar to the open record

*Click **Find Similar** . Use the default weightings to calculate nearness; do not open the **Nearness Settings** dialogue.*



• Apply additional design constraints
*Click **Selection Project**. This creates a selection project and ranks the results by nearness to the reference record.*

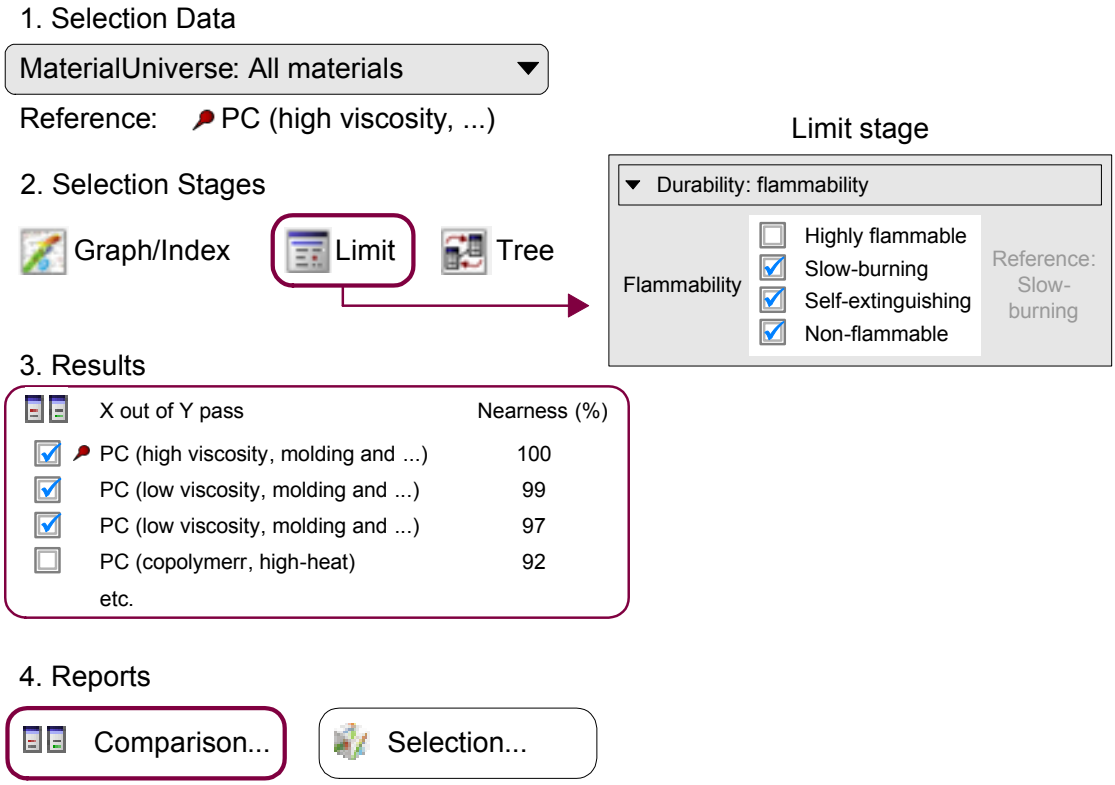
• Exclude materials that have poorer flammability than the reference:

	Slow-burning
FLAMMABILITY	Self-extinguishing
	Non-flammable

Add a Limit Stage and select the correct flammability options from the drop-down.

• Compare the selection results
*Select the check boxes for **PPO/PS** and **PBT**. Under **Reports**, click **Comparison**.*

• Use the comparison table to check for other significant differences in performance, for example, ELONGATION.


1. Selection Data
MaterialUniverse: All materials
Reference: PC (high viscosity, ...)
2. Selection Stages
Graph/Index
Limit
Tree
Limit stage
Durability: flammability
Flammability
Highly flammable
Slow-burning
Self-extinguishing
Non-flammable
Reference: Slow-burning
3. Results
X out of Y pass
Nearness (%)
PC (high viscosity, molding and ...) 100
PC (low viscosity, molding and ...) 99
PC (low viscosity, molding and ...) 97
PC (copolymerr, high-heat) 92
etc.
4. Reports
Comparison...
Selection...

4.8 Process Selection

Exercise 14 Selecting Processes

Select ProcessUniverse: Shaping processes.

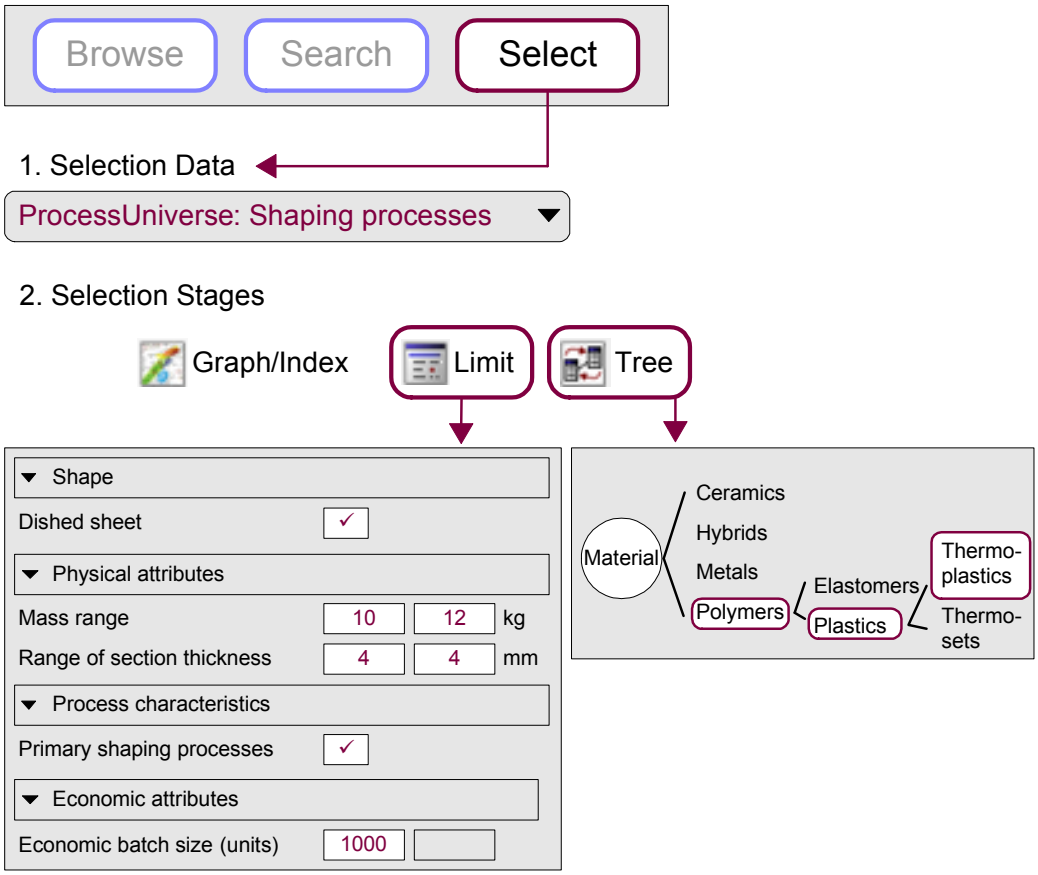
• Find PRIMARY SHAPING PROCESSES to make a component that has:

SHAPE	Dished sheet
MASS	10 - 12 kg
SECTION THICKNESS	4 mm
ECONOMIC BATCH SIZE	> 1000

Add a Limit Stage with five criteria.

• Refine this search to only include THERMOPLASTIC materials
Add a Tree Stage and select MaterialUniverse - Polymers - Plastics - Thermoplastics.

Example results: Thermoplastic composite molding, Spray-up, Rotational molding, Compression molding.



4.9 Saving, Copying, and Report Writing

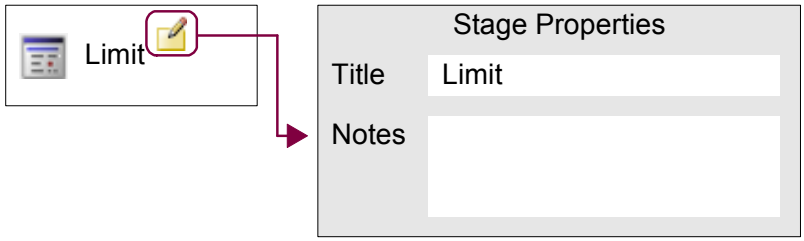
Exercise 15 Adding Comments and Saving a Project

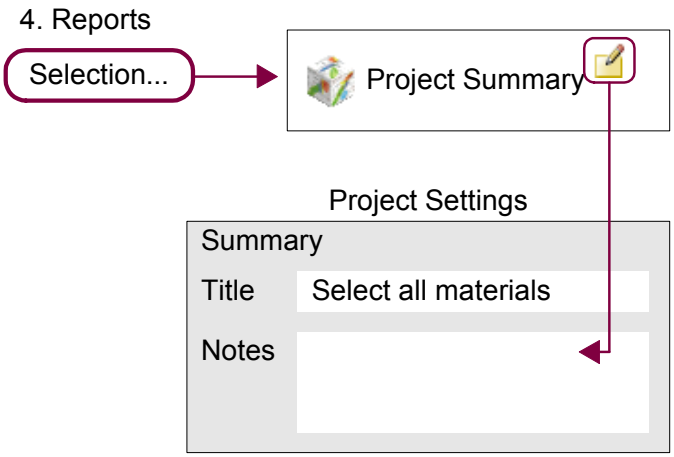
You can add comments to a selection project as a reminder of why you have applied certain constraints and objectives. Comments are displayed on mouse-over in the selection report, and are saved in the project file.

Comments can be added to each selection stage in a project.

*Click the **Notes** icon* *in the stage window heading, then type in the dialog.*

Comments can also be added to the selection report summary. For example, adding information on which material was finally selected, and the reasons why, provides full traceability of the material selection.





• Save the project
*Go to the **File** menu - **Save Project**. Give the project a filename and directory location; the project will be saved with the file extension **.ces**.*

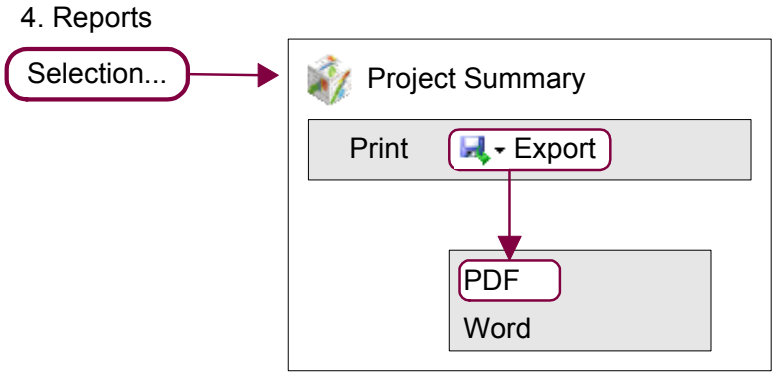
Exercise 16 Exporting and Copying

Reports can be exported to a PDF or Word document.

• Generate a SELECTION REPORT

• Export the report as a PDF

*Click **Export** and select **PDF**.*
Note: You will require a PDF reader such as Adobe Reader to view the exported selection report.



Charts, records and results lists, however, can be copied and pasted into a word processing application.

• Generate a chart. Copy and paste the chart into a document
*Click on the chart. Either: right-click on the chart and select **Copy**; or press CTRL+C to copy the chart to your clipboard. Paste from your clipboard to the document.*

• SEARCH for a record and display the datasheet. Copy and paste the datasheet into a document

• GENERATE a RESULTS list using SELECT. Copy and paste the full list into a document
*Right-click in **Results** and click **Select all**. Either: right-click on the highlighted list and select **Copy**; or press CTRL+C once the list has been highlighted.*

• Copy individual results from the results list into a document
Use SHIFT+click or CTRL+click to highlight selected records.

• Try editing the document you have created

Chaper 5 Getting the Most Out of CES Selector

The following exercises introduce some additional tools and features designed for increased productivity.

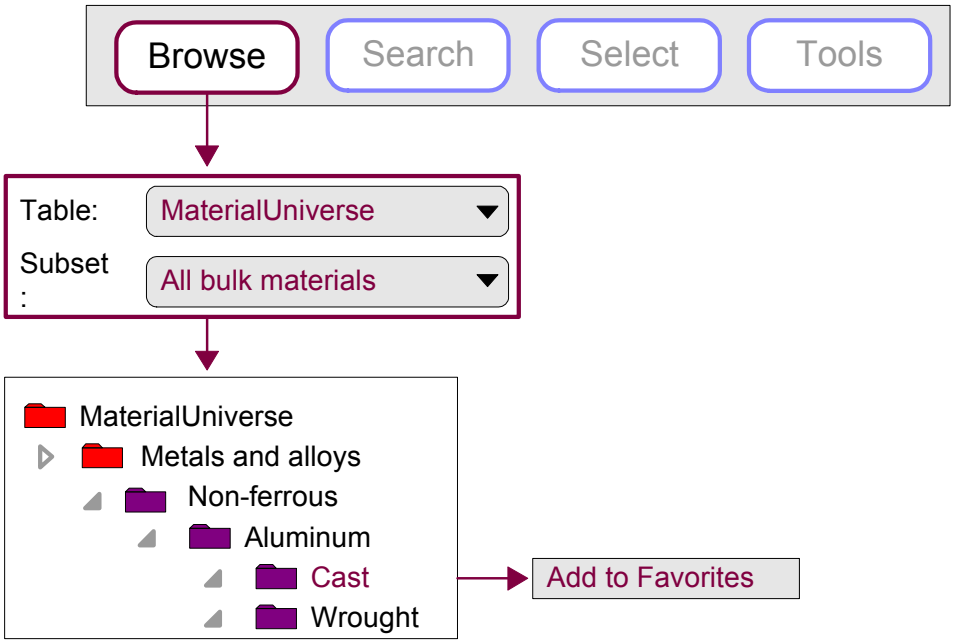
5.1 Custom Selection

Exercise 17 Favorites

The favorites feature enables users to highlight their favorite records e.g. a company's preferred materials.

• Browse to the CAST ALUMINUM folder

• Add the folder as a favorite
*Right-click on the folder name and select **Add to Favorites**; on the tree and datasheet, the material will now be marked with a star to indicate it is a favorite.*



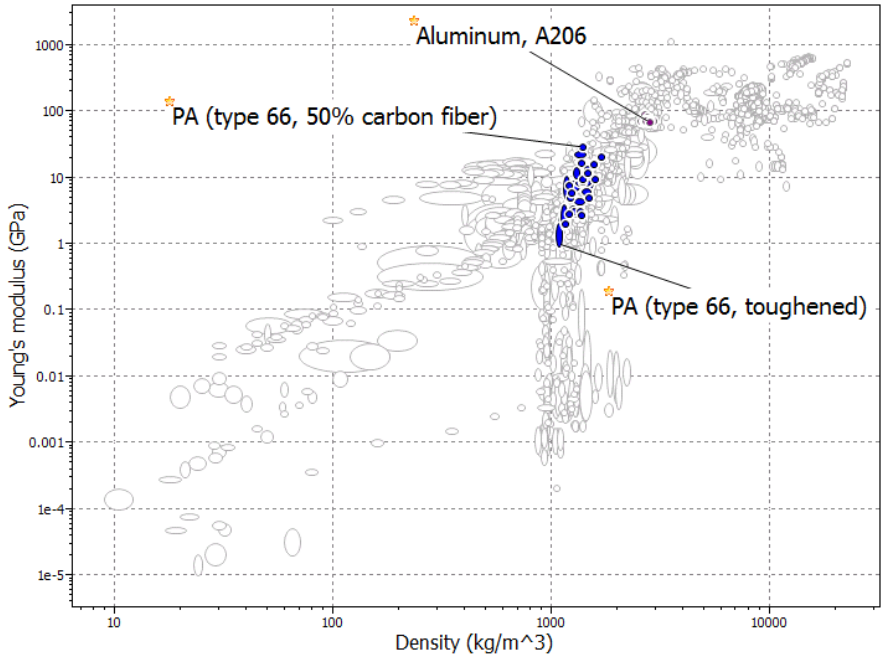
• Add the TYPE 66 PA folder as a favorite as well
Expand Polymers - Plastics - Thermoplastics - PA (Polyamide/Nylon)

Select MaterialUniverse: All bulk materials

• Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ)
As in Exercise 6.

• Show Favorites

*Click **Favorites** ; all the materials that are not favorites are grayed out. Click on a favorite, colored material to add a label.*



• Clear Favorites
*(Go to the **Tools** menu - **Favorites** - **Clear**)*

• RETAIN THIS STAGE FOR THE NEXT EXERCISE

Exercise 18 Adding User Defined Records

New materials are continuously being developed and introduced onto the market. These materials can be added and compared with other materials in the database using the User Defined Record feature.

• Add a second SELECTION STAGE with the following constraint:

THERMAL EXPANSION COEFFICIENT	< 100 µstrain/°C

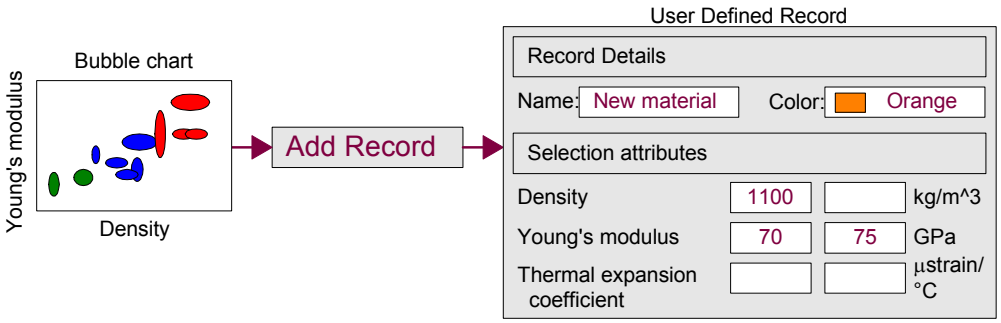
Add a Limit Stage with one criterion.

• Add your own record
*Right click in the bubble chart and select **Add Record**.*

• For the User Defined record, set the following values:

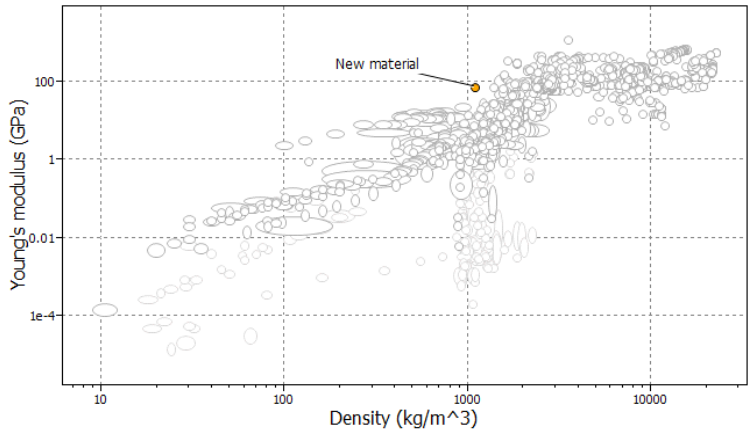
NAME	New material
DENSITY	Min. 1100 kg/m^3
YOUNG'S MODULUS	70 - 75 GPa

*Click **OK** when finished. The new record will be shown on the Graph Stage with the default color as orange.*



• Show the User Defined record

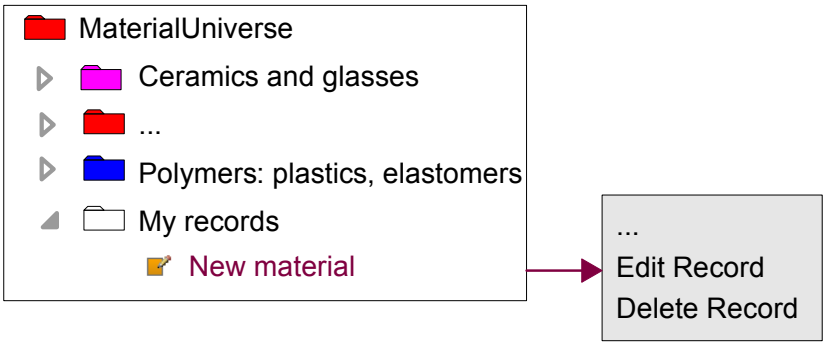
*Click **Show User Defined Records** ; all the materials that are not user defined are grayed-out.*



When a record is added from a chart, only the selection attributes are shown for data entry. User-defined records do not fail stages when no value has been entered for a specified constraint (such as thermal expansion in this example).

A user-defined record appears on the **Browse** tree under **My records**.

User defined records are saved in the selection project file, not the database. You may edit or delete a user-defined record.



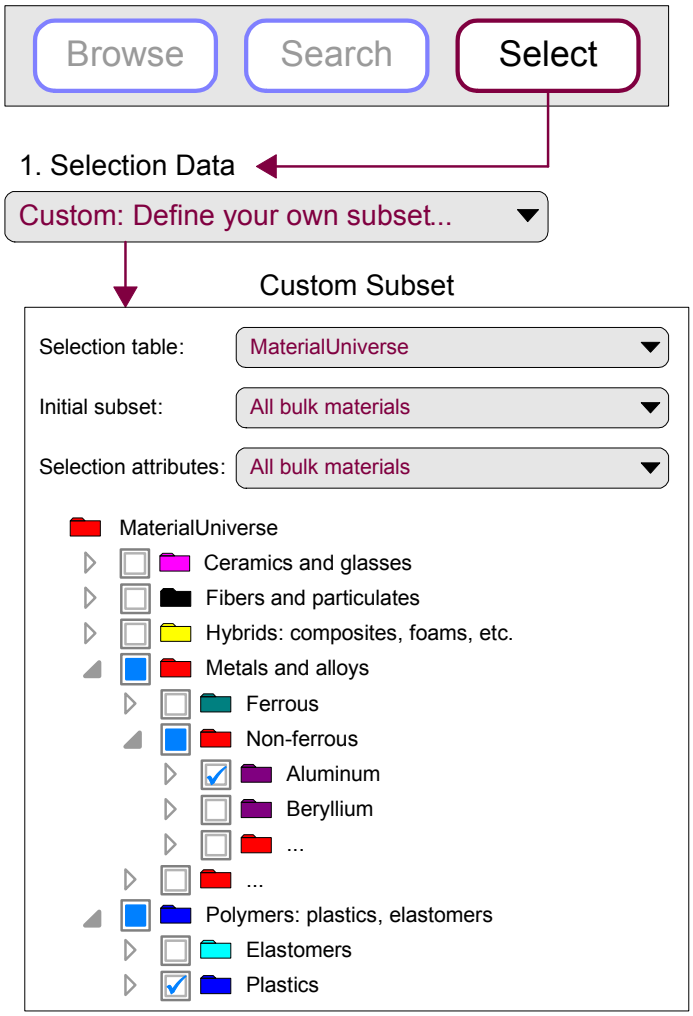
• DELETE the LIMIT STAGE, but leave the initial GRAPH STAGE, as this will be needed for the next exercise

• SAVE the project

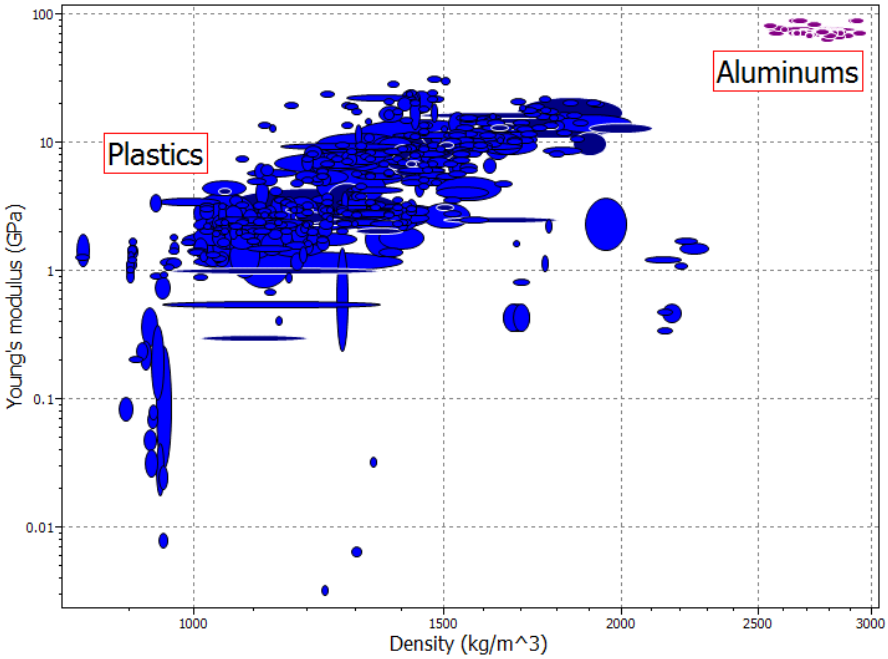
Exercise 19 Selection with a Custom Subset

The CES Selector databases are supplied with a range of standard subsets (e.g. All bulk materials, Metals, Magnetic materials, etc.) which enable users to restrict their material selection to certain material groups within the database. The custom subset feature enables users to define their own subsets.

• Change the Selection table to CUSTOM materials and select ALUMINUM and PLASTICS and see that the bubble chart updates.
*In the **Custom Subset** dialog, use the checkboxes to include or exclude records and folders.*



Note: The Selection attributes setting defines what properties will be available in graph and limit selection stages.

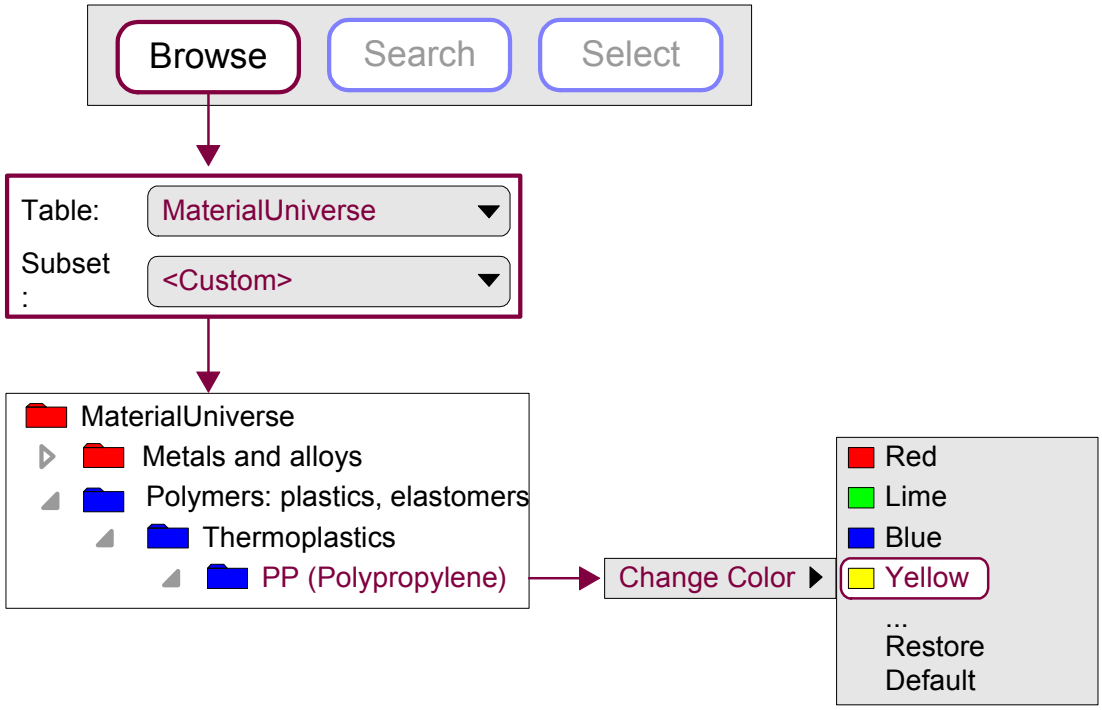

Aluminums
Plastics
Young's modulus (GPa)
100
10
1
0.1
0.01
1000
1500
2000
2500
3000
Density (kg/m^3)

Exercise 20 Record Coloring

The CES Selector databases use a standardized color scheme for displaying records (e.g. dark blue for plastics). These default colors can be changed so that particular records can be highlighted.

• Browse to the POLYPROPYLENE folder

• Change the folder color to YELLOW
*Right-click on the folder name and select **Change Color** then **Yellow**.*



Note: Record colors can also be changed by right-clicking on a record in a graph stage or the selection results list.

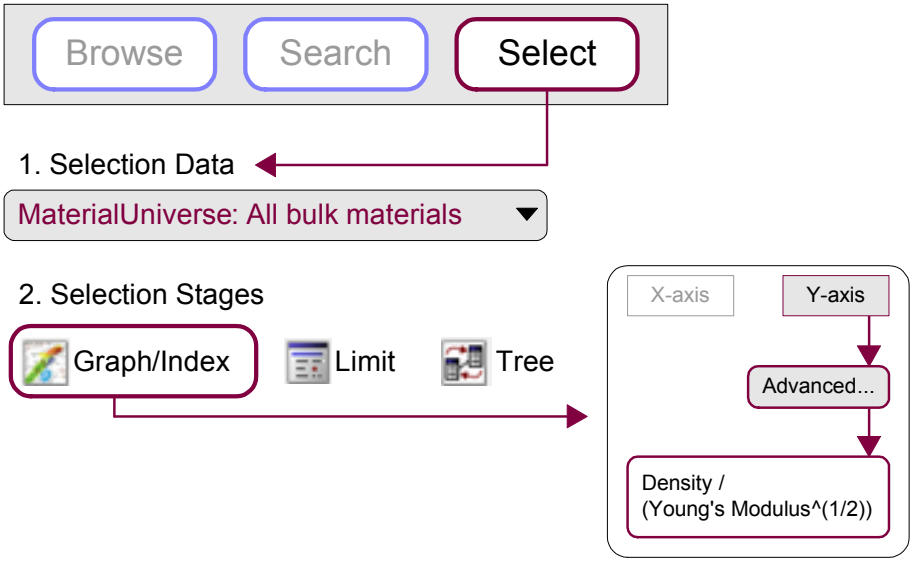
• Confirm that the BUBBLE CHART coloring has updated

• DELETE THIS STAGE

Exercise 21 Plotting a Combined Property

Many engineering applications require combined properties to be optimized. For example, specific stiffness (Young's modulus / density) in aerospace, and thermal diffusivity (thermal conductivity / (density . specific heat)) in thermal applications. These types of properties can be plotted using the advanced property feature.

• Make a BAR CHART of the combined property DENSITY / (YOUNG'S MODULUS ^ (1/2))
*In the Graph Stage Wizard, under the **Y-Axis** tab, click **Advanced**. In the **Set Axis** dialog, select an attribute and click **Insert** to build the expression. Leave the x-axis with no attribute set, to generate a bar chart.*



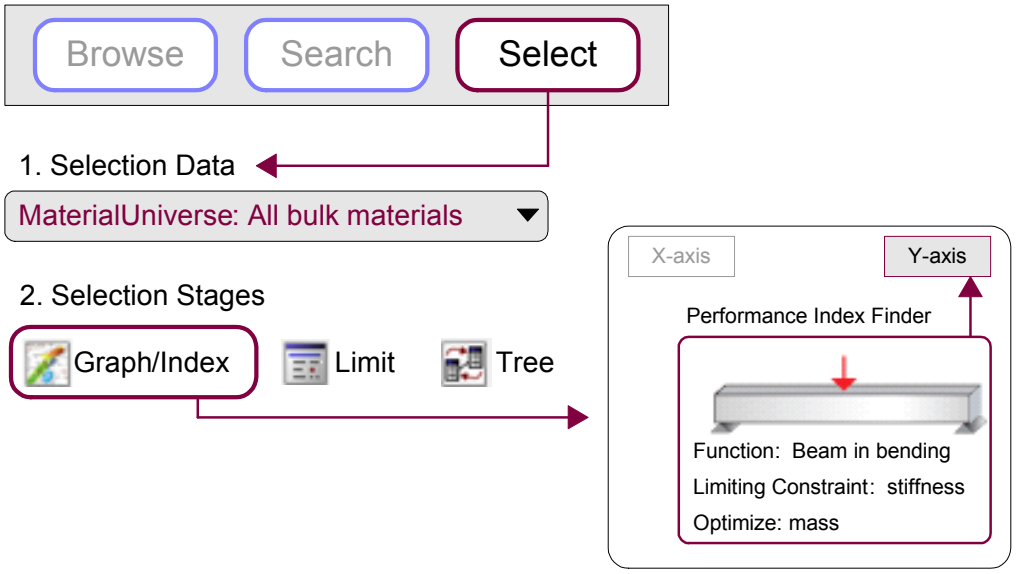
• DELETE THIS STAGE

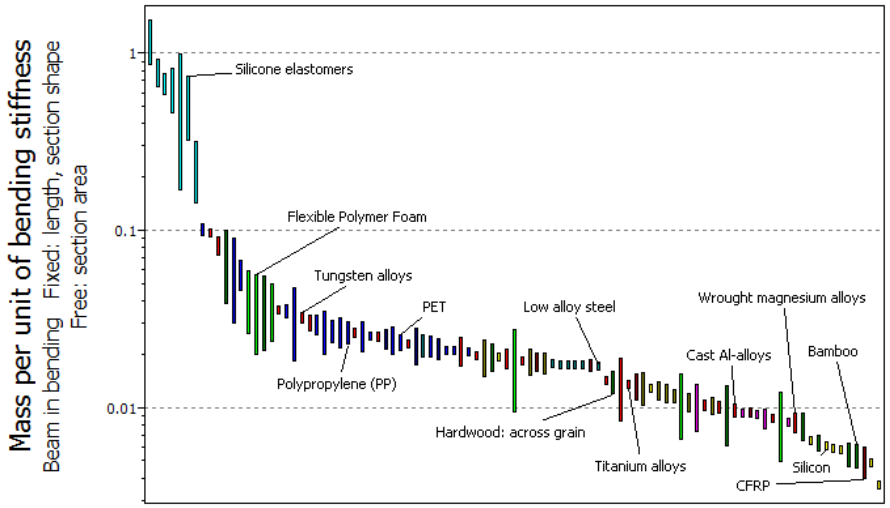
5.2 Performance Indices

One of the main components of the rational material selection technique is the use of performance indices. These are combined properties (e.g. Young's modulus / density) that allow the function of a design to be optimized for a particular application. The performance index finder enables users to quickly identify (and plot) the performance indices that are applicable to their design.

Exercise 22 Performance Index Finder

• Make a BAR CHART of the performance index for minimizing the mass of a stiffness-limited beam, loaded in bending
*In the Graph Stage Wizard, under the **Y-Axis** tab, select **Performance Index Finder**. Select the **Beam in bending** function. Set **length, section shape** as fixed variables, **stiffness** as the limiting constraint, and optimize for **mass**.*

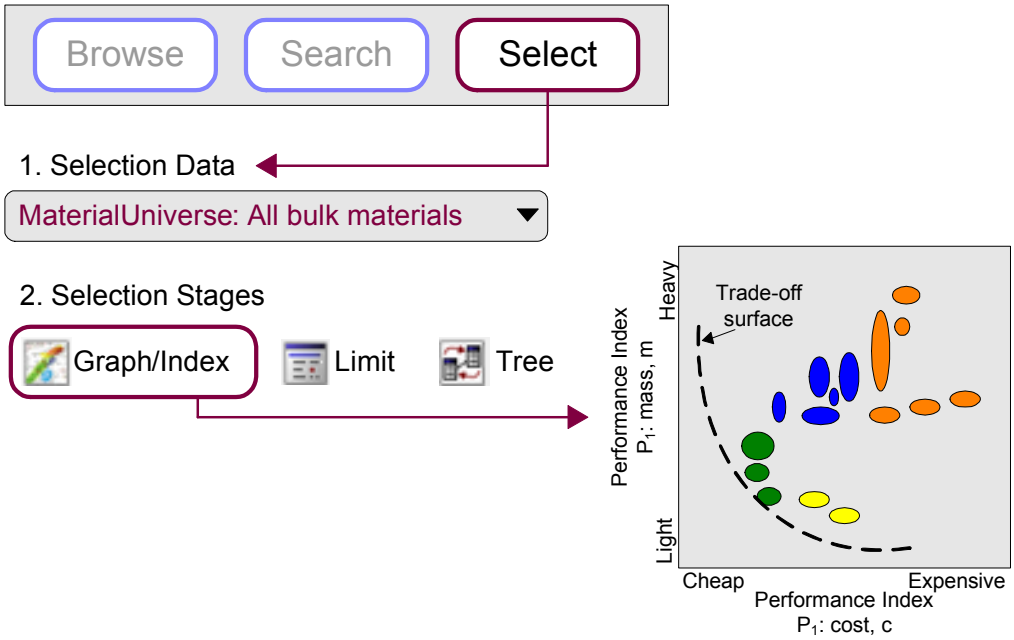




Exercise 23 Selection with a Trade-off Plot

Many designs require a compromise to be made between competing objectives, for example, maximize performance and minimize cost. The influence of this 'trade-off' on material choice can be studied by generating a trade-off plot, where candidate materials lie along a hypothetical curve or trade-off surface (see picture). Optimal materials, for a particular application, are identified by making a judgment on the relative importance of the two objectives (e.g. in aerospace, high performance is more important than low cost).

• Make a BUBBLE CHART of the performance index BEAM IN BENDING, limited by STIFFNESS
*Set the y-axis to optimize **mass** and the x-axis to optimize **cost**.*



The materials at on or near the trade-off surface offer the best compromise for minimizing mass and cost.

Note: The trade-off surface is not plotted by CES Selector.

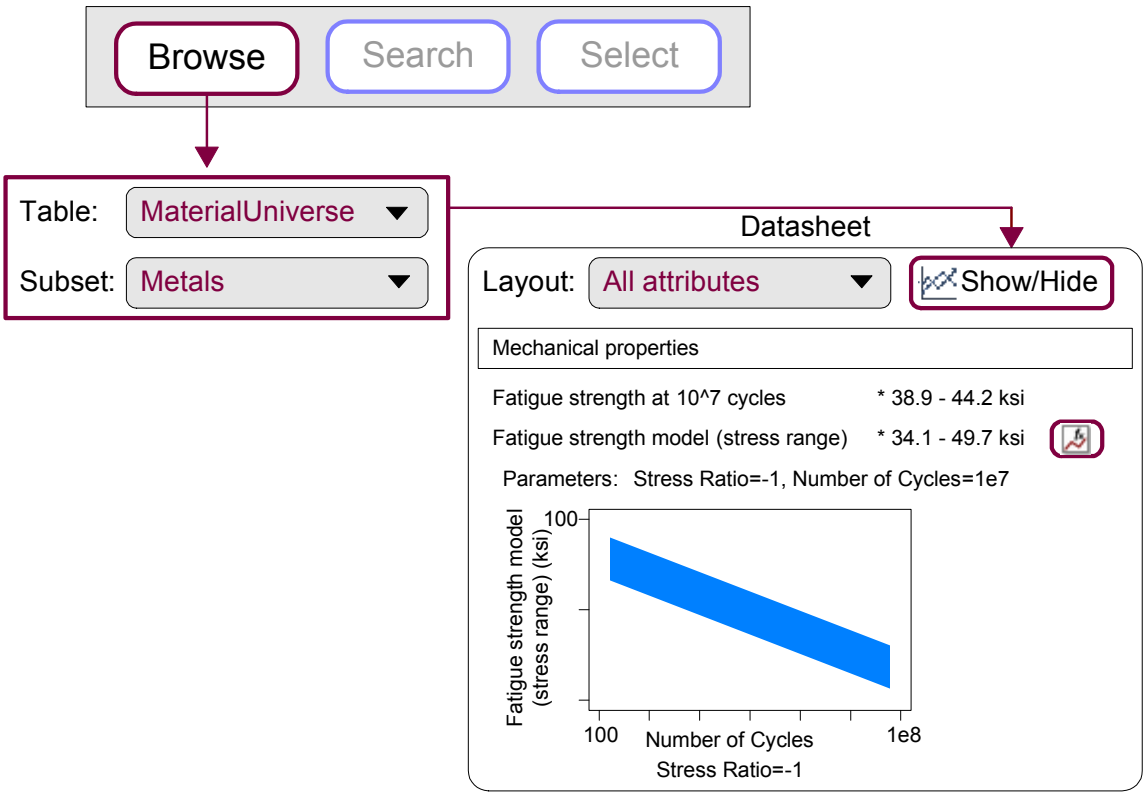
5.3 Functional Data

Some properties within the databases are stored as functional data, meaning that data is available for a number of different conditions. This allows users to readily incorporate the conditions of their application into their selection project. For example, using the 'Fatigue strength model' the user can specify both the stress ratio and number of cycles for the fatigue strength.

Exercise 24 Viewing Functional Data

• Find a record for STAINLESS STEEL. If the functional data graphs are not already visible, set them to be shown

Click **Show/Hide** to toggle functional data graphs on the datasheet. Alternatively, click the graph buttons to open a graph in a new window and view the equation or data points.



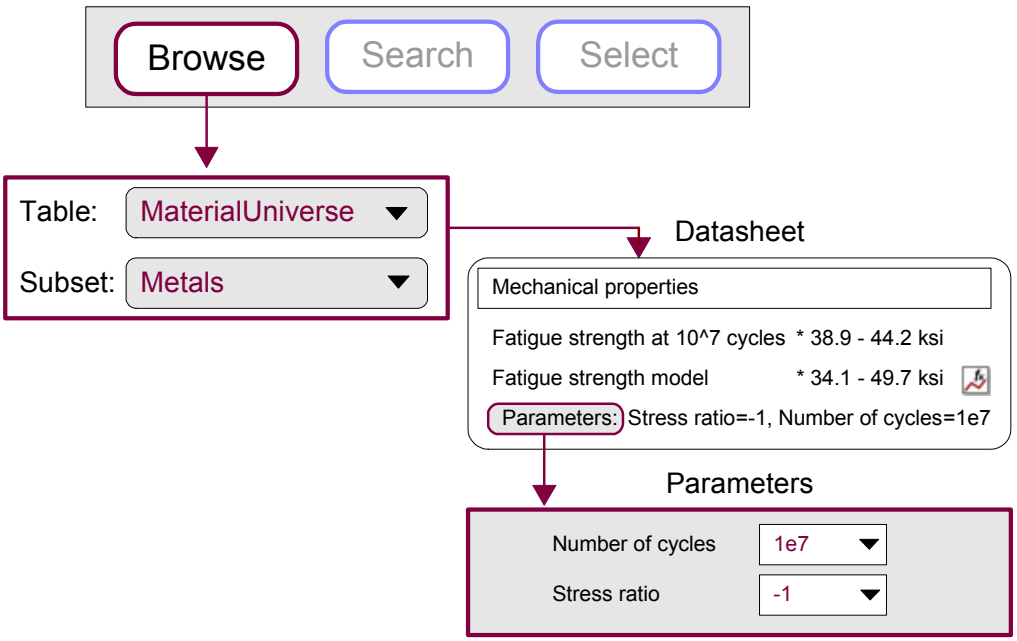
Exercise 25 Setting Parameters for Functional Data

The parameter values for functional data apply to all applicable functional data types within the datasheet and to all datasheets in the selection project. The parameter values can be changed using the **Parameters** hyperlink.

Note: The value for Fatigue strength model is calculated at the given parameter values for Stress ration and Number of cycles.

• Find a record for STAINLESS STEEL

• Change the parameter value for NUMBER OF CYCLES
*Click the **Parameters** link and set a new value in the dialog, then click **OK**. The value in the datasheet will be updated.*



• View the updated project setting
*Go to the **Select** menu and **Project Settings**. The updated settings are under the **Parameter Values** tab.*

5.4 Find Similar with Additional Criteria

If a project has additional or different constraints than are captured by the default nearness criteria in Find Similar, there are two ways to refine the results.

Exercise 26 Find Similar with Limits

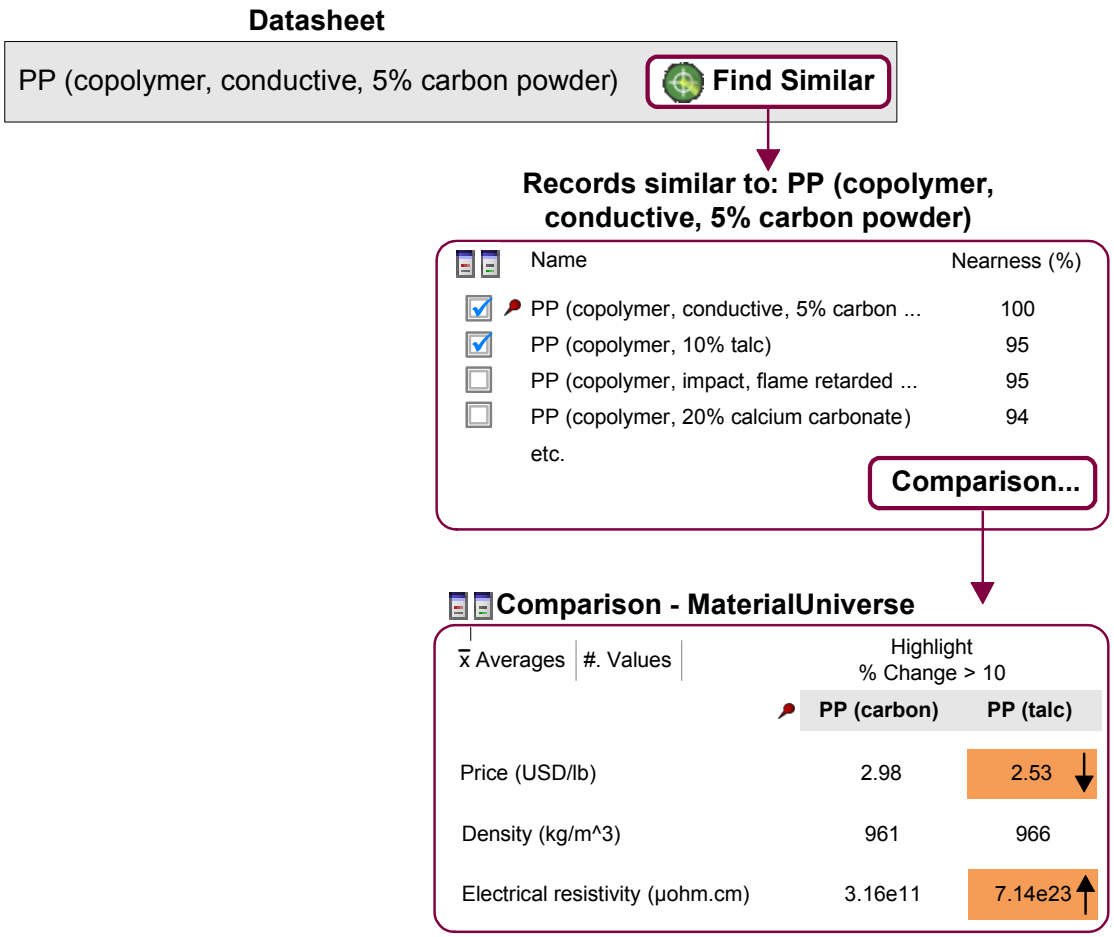
• Open the record for POLYPROPYLENE (COPOLYMER, CONDUCTIVE, 5% CARBON POWDER)

• Find records similar to this one

*Click **Find Similar** . Use the default weightings to calculate nearness; do not open the **Nearness Settings** dialogue.*

• Compare the current material with the nearest alternative
*Select the closest record from the list of results - PP (copolymer, 10% talc) - and open a comparison table using **Comparison**.*

The comparison table is highlighted where there is a difference between the original (reference) and alternative materials. The reference material in this exercise was chosen specifically because of it has low electrical resistivity, however the nearest match does not. This is because the default criteria for nearness in this table do not account for electrical resistivity. This can be changed manually.

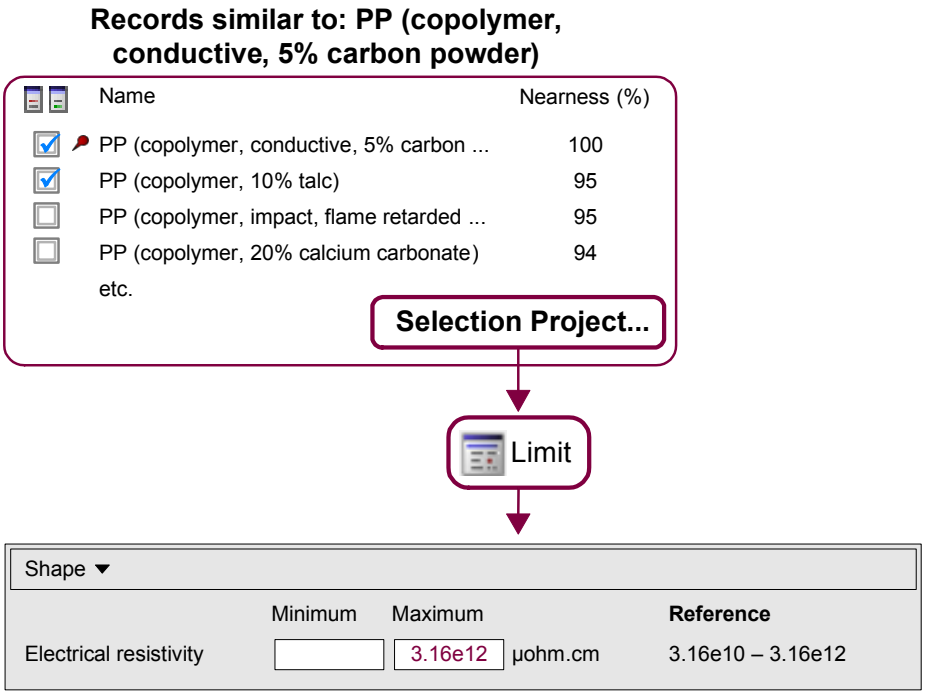


The nearest materials in the results have similar physical properties to the reference material (density, yield strength, Young's modulus). However, the original material may have been chosen for other characteristics. In this case, the polymer is conductive (has a low electrical resistivity).

The results from Find Similar can be used as the basis of a Selection Project. In this case, a Limit Stage can be used to filter on the additional requirement for conductivity.

• Create a SELECTION PROJECT using the results
*Click **Selection Project**. The results are loaded into a new project, ranked by nearness.*

• Add a Limit Stage to filter for electrical resistivity that is the same or lower than the reference material
*In a new Limit Stage, set the **Maximum** value for electrical resistivity to **3.16e12**, which is the maximum value for the reference record. **Apply** the stage.*



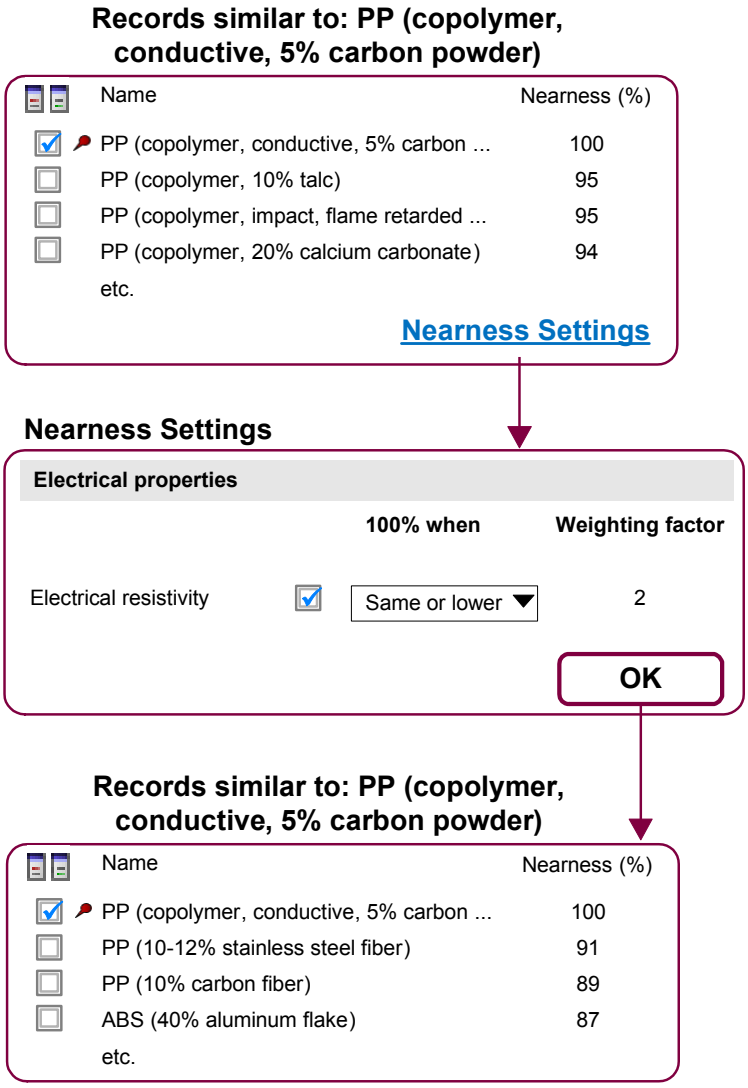
Example results, with Nearness (%): PP (10-12%, stainless steel fiber) 88%, PP (10% carbon fiber) 86%, ABS (40% aluminum flake) 84%.

Exercise 27 Changing the Find Similar Nearness Settings

Instead of filtering on additional attributes, it is possible to change the criteria used for calculating nearness to take account of different requirements.

• Find records similar to POLYPROPYLENE (COPOLYMER, CONDUCTIVE, 5% CARBON POWDER)
*Open the datasheet and click **FindSimilar**.*

• Re-calculate the list of alternative materials, taking ELECTRICAL RESISTIVITY into account and prioritizing those results with resistivity that is the same or lower than the reference
*Click the **Nearness Settings** link on the **Records Similar to** dialog. Under Electrical Properties, tick Electrical resistivity. Set 100% when the value is Same or lower and increase the Weighting factor to 2. Click OK to generate the new results.*



Note that these results are conceptually different to those from the previous exercise. These results rank similar materials, taking into account the conductivity, but there is not a fixed upper limit as there was when filtering using the Limit Stage. Materials with a higher conductivity than the reference will still be included in these results.

5.5 Eco Audit

The Eco Audit Tool, which is an optional add-on, estimates the energy used and CO2 produced during five key life phases of a product (material, manufacture, transport, use, and end of life) and identifies which is the dominant phase. This is the starting point for eco-aware product design, as it identifies which parameters need to be targeted to reduce the eco-footprint of the product.

A brand of bottled mineral water is sold in 1 liter PET bottles with polypropylene caps. A bottle weighs 40 grams; the cap 1 gram. Bottles and caps are molded, filled, and transported 550 km from the French Alps to England by 14 tonne truck, refrigerated for 2 days and then sold. The overall life of the bottle is one year.

An example product file for this case study is installed with CES Selector in the **Samples** folder, with the filename **Bottle mineral water.prd**.

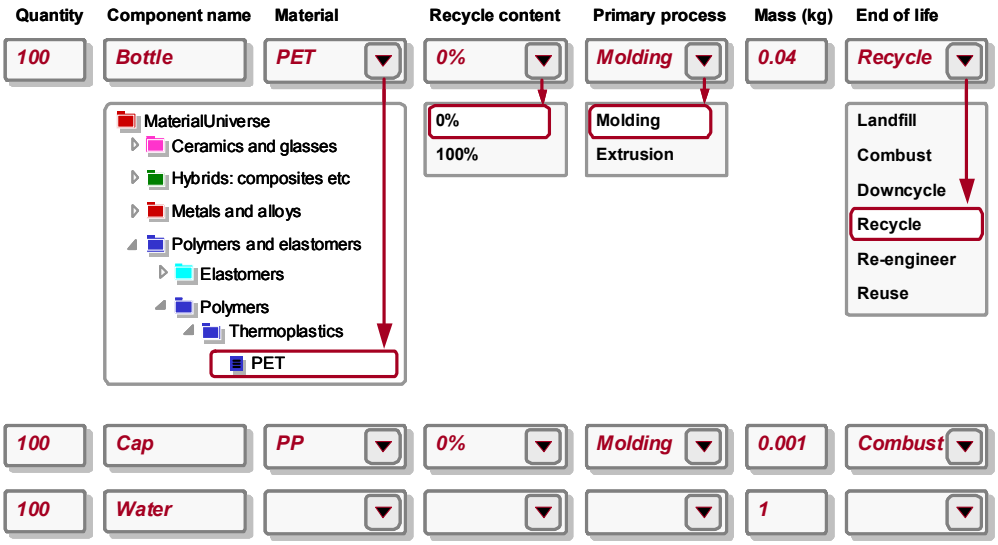
Product Definition

The following details how the example product file has been created.

For an explanation of the calculations used at each stage, click the Help icon in the heading.

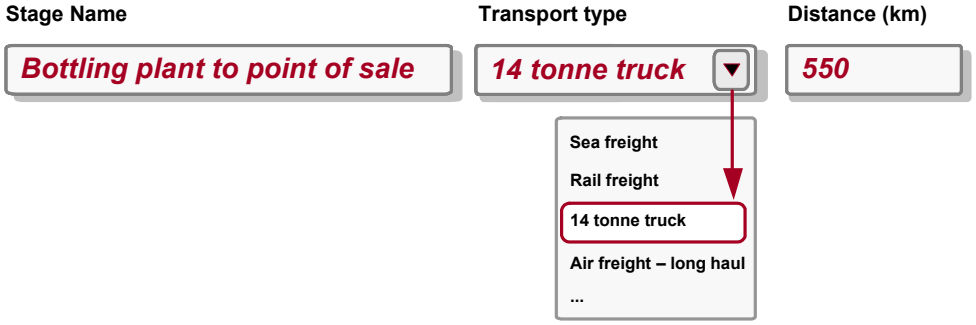
1. Material, manufacture, and end of life

Bill of materials (BoM) and primary processing techniques.



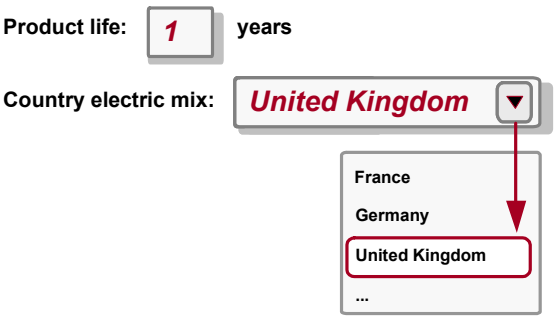
2. Transport

Transportation from site of manufacture to point of sale.



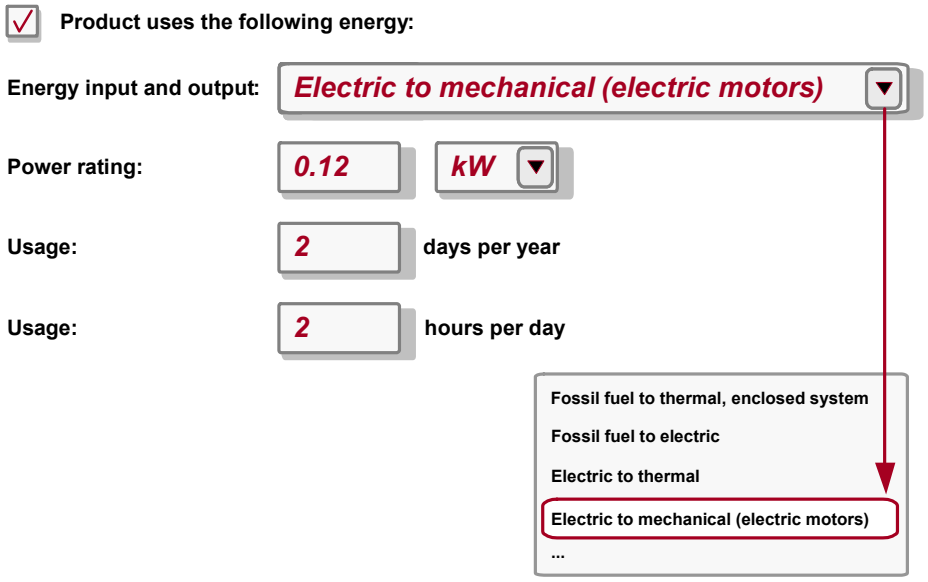
3. Use

Product Life and Location Use



Static Mode

Energy used to refrigerate product at point of sale (average energy required to refrigerate 100 bottles at 4°C = 0.12kW.

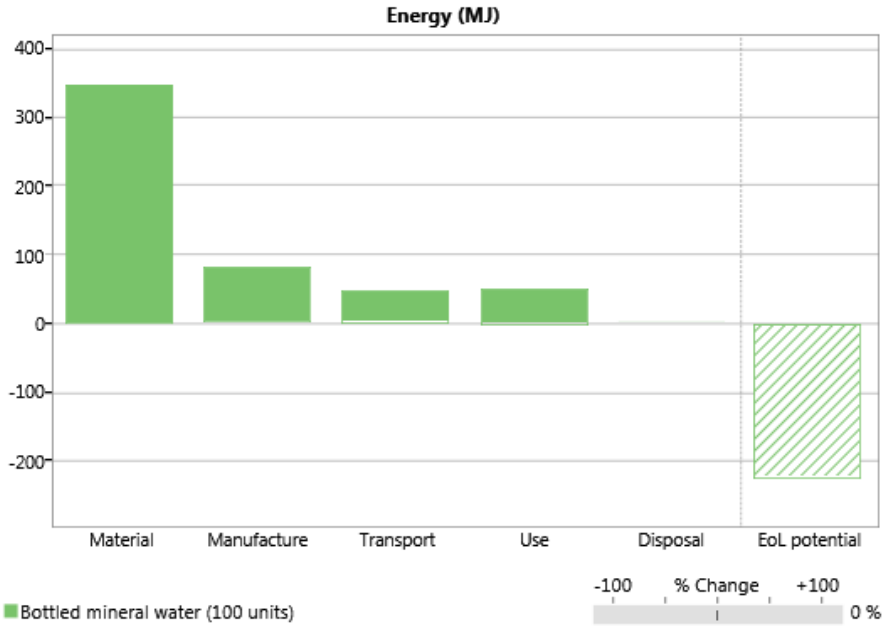


4. Report

Summary chart

enables rapid identification of the dominant life phase.

Toggle between views of energy usage or CO_2 footprint.



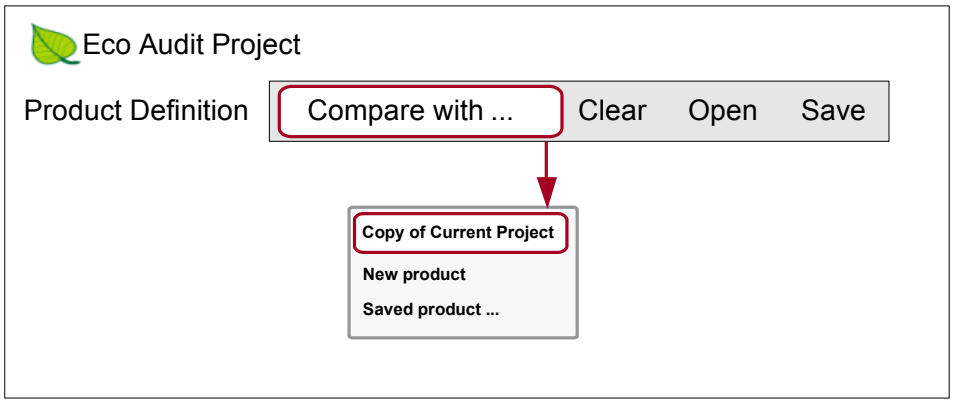
The chart shows that, in this project, Material is the dominant life phase. Each life phase can be clicked to show guidance on strategies to reduce its impact.

Detailed report

provides a component by component breakdown of each life phase, enabling the main contributors to the dominant life phase to be identified.

Exercise 28 Compare Eco Audits

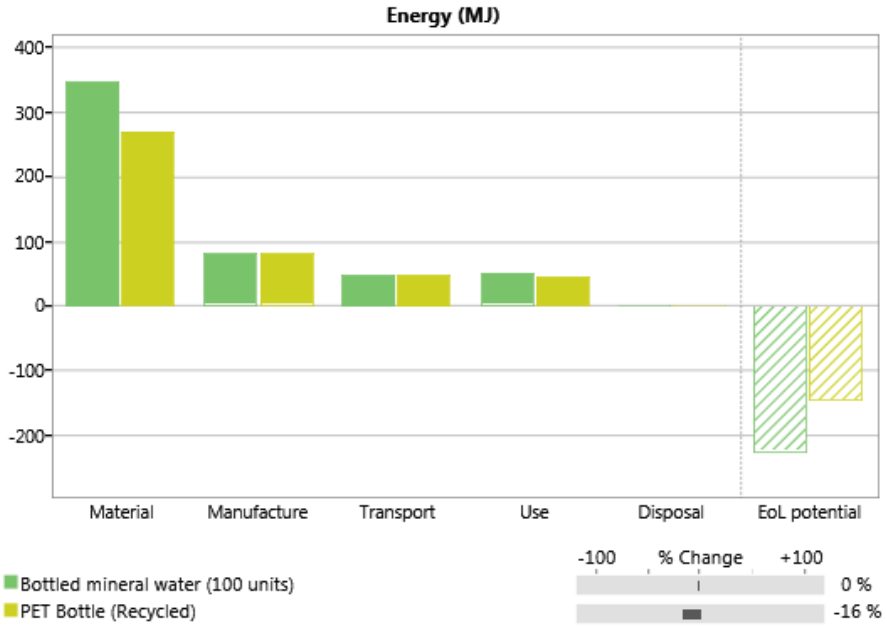
• Create a copy of the current product for comparison
*Click **Compare with** and select **Copy of current product**.*



• Set the following values in for the new product:

NAME	PET Bottle (Recycled)
RECYCLED CONTENT	35%

• Generate the SUMMARY CHART



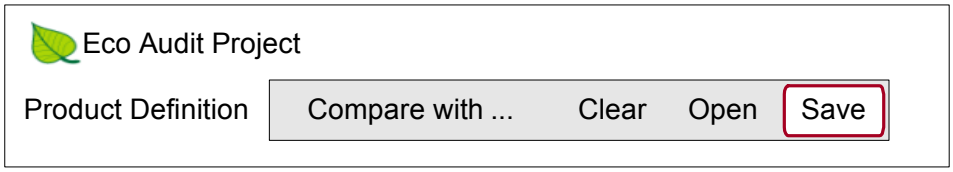
The first life energy (not including EoL potential) is reduced by 16%.

Note: The chart can be copied into a document or printed using **Copy** and **Print** at the top of the chart window.

Exercise 29 Saving and Exporting

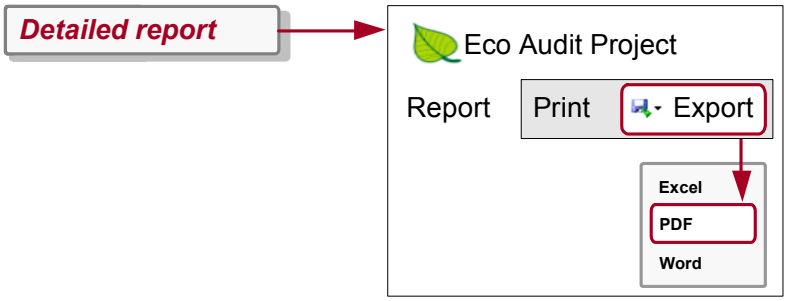
Eco Audit projects do not form part of a selection project and therefore need to be saved separately.

• SAVE the product definition



• GENERATE the Eco Audit report

• EXPORT the report as a PDF
Note: You will require a PDF reader such as Adobe Reader to view the exported report.



5.6 Hybrid Synthesizer

Hybrid materials and structures combine the benefits of two or more materials to produce new materials that exhibit unique combinations of properties. For example, both composite materials and sandwich panels are commonly used in lightweight structures. The Hybrid Synthesizer enables the performance of these structures to be predicted and compared with other materials in the database.

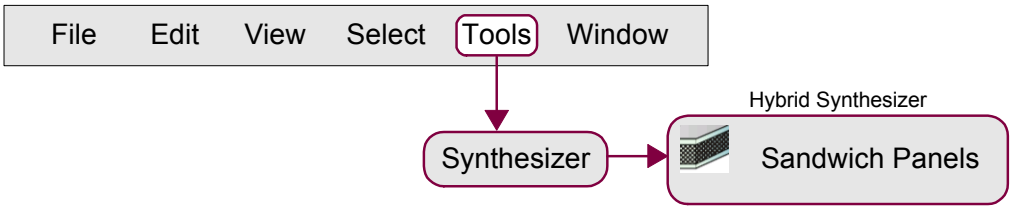
Exercise 30 Sandwich Panels Model

Select MaterialUniverse: All bulk materials

• Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ)
As in Exercise 6.

• Use the SANDWICH PANELS MODEL to create synthesized records for a family of hybrid materials

*Use **Synthesizer** on the toolbar or go to the **Tools** menu - **Synthesizer**. In the dialog, select **Balanced Sandwich Panels**.*



• Set the SOURCE RECORD values:

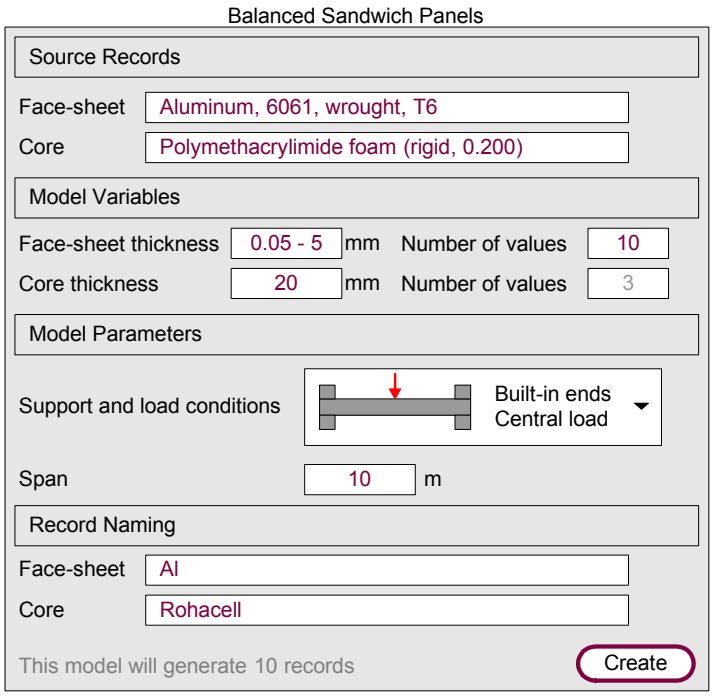
FACE-SHEET	Aluminum, 6061, wrought, T6
CORE	Polymethacrylimide foam (rigid, 0.200)

*Click **Browse** and locate the records in the tree.*

• Leave the default values for MODEL VARIABLES and MODEL PARAMETERS

• Set the RECORD NAMING values:

FACE-SHEET	Al
CORE	Rohacell



• CREATE the synthesized records

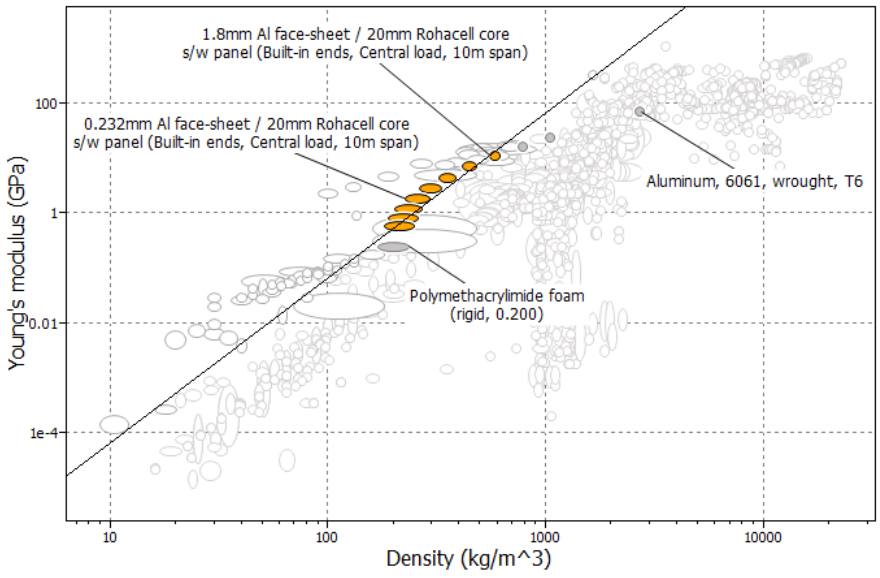
*Click **Create** and then **Finish**. The new synthesized records will be shown on the **Graph Stage**.*

Note: The Help icon in the Synthesizer dialog opens a list of the calculations used for the current model type.

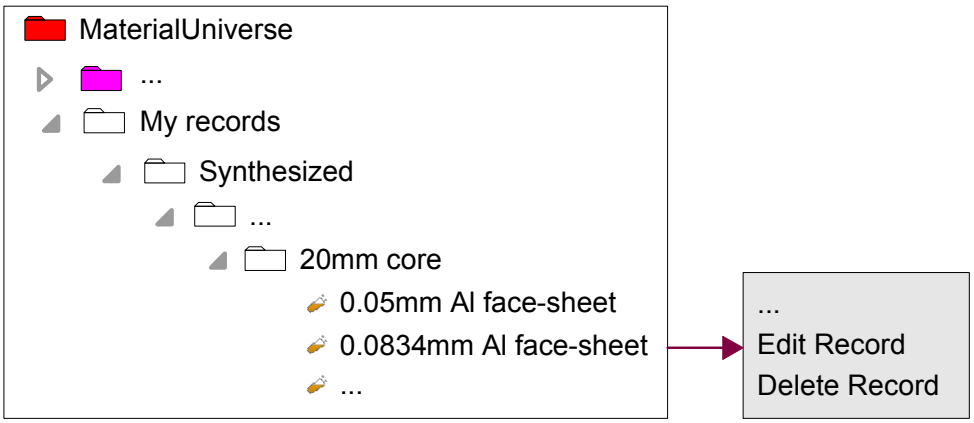
• Plot a LINE SELECTION corresponding to a lightweight, stiff panel in bending $\rho/E_f^{1/3}$

*Click **Gradient-Line Selection** and enter a slope of 3.*

• Add labels to the source records and some of the synthesized records

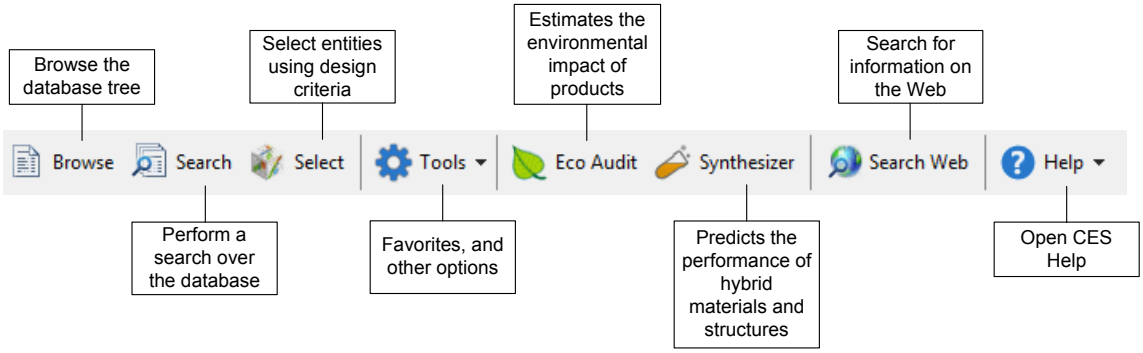


Synthesized records appear on the Browse tree under **My Records** and may be edited or deleted in a similar way to User Defined records.

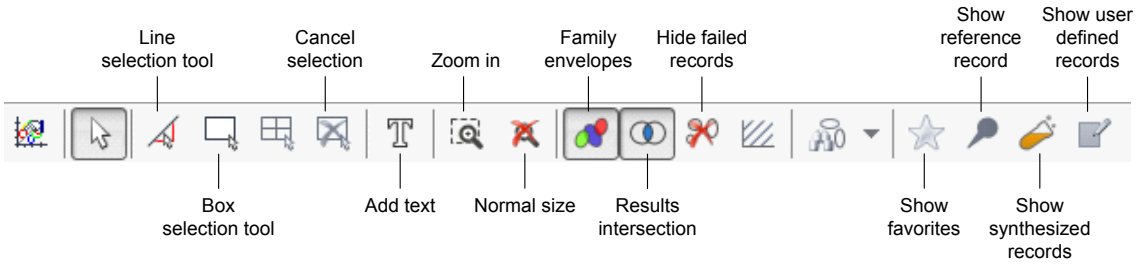


Chaper 6 Toolbars and General Information

Standard Toolbar



Graph Stage Toolbar



File Types

*.gbd	Granta Database file
*.ces	CES Selector Project file
*.cet	Selection Template file
*.frl	Favorites file
*.prd	Eco Audit Product Definition file

Options for Preferred Currency and Units

Settings	Database Options	
	Preferred Currency	**Preferred Unit System**
<Automatic>	The Regional Setting from the operating system for currency is used to view data. This will appears as <Automatic - *Regional Currency*>, e.g. <Automatic - GBP>.	Th Regional setting from the operating system for unit system is used to view data. This will appear as <Automatic - *Regional Units*> e.g. <Automatic - Metric>.
<None>	Data is displayed using the same currency as it is stored with in the database.	Attribute data is displayed using the same units as the data is stored with in the database.
Named setting	Named currency is used to display data.	Named unit system is used to display data.